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A REPORT ON

ALTERNATIVE METHODS OF EFFLUENT DISPOSAL

CITY AND COUNTY OF SAN FRANCISCO

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BROWN AND CALDWELL, CONSULTING ENGINEERS

SAN FRANCISCO, CALIFORNIA

A REPORT ON

ALTERNATIVE METHODS OF EFFLUENT DISPOSAL

CITY AND COUNTY OF SAN FRANCISCO

February, 1969

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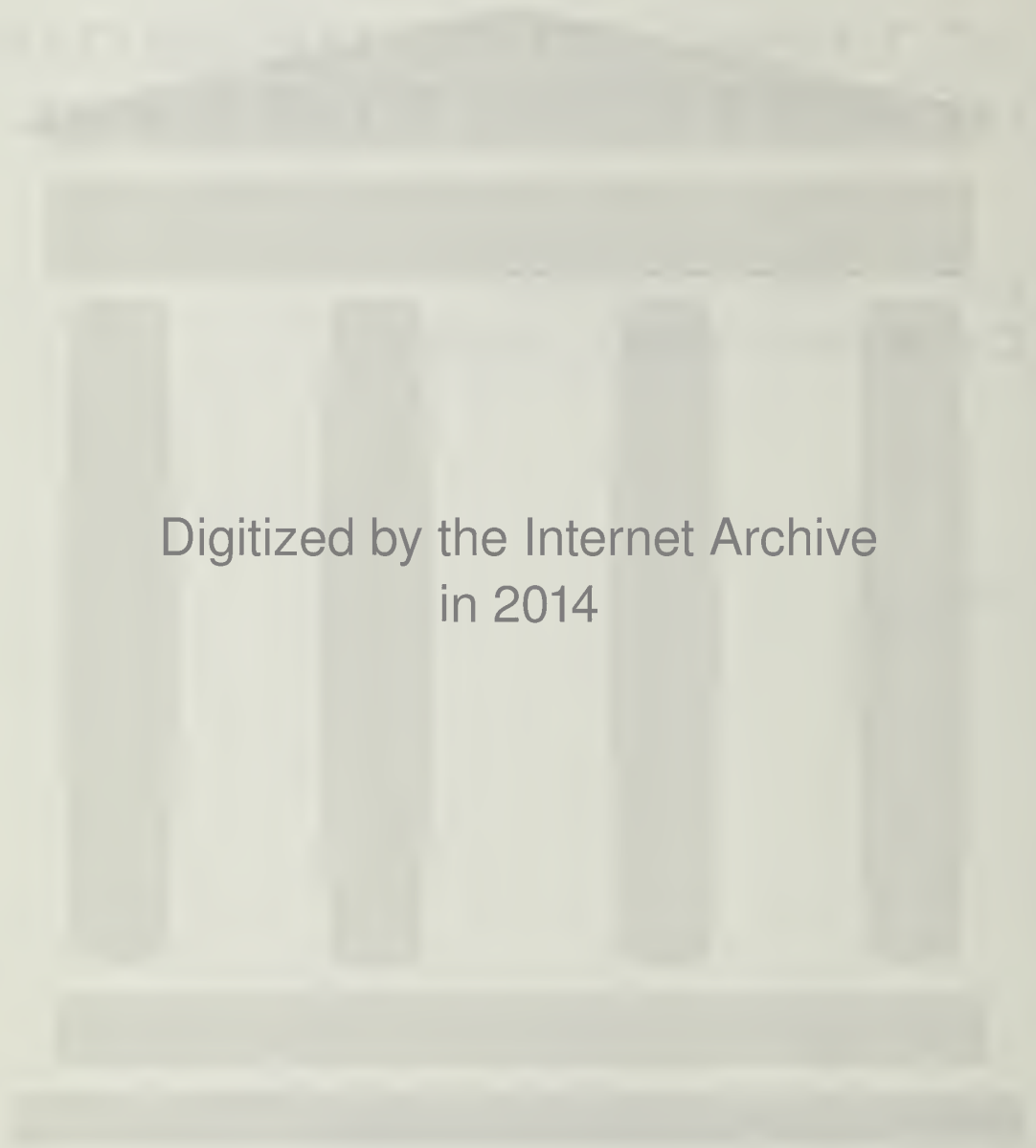

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February 25, 1969

F 183A

Mr. S. M. Tatarian
Director of Public Works
City and County of San Francisco
San Francisco, California

Dear Sir:

As provided under the terms of our agreement for engineering services dated June 12, 1968, we submit herewith a report on a long-range program for the disposal of dry weather sewage flows from the City and County of San Francisco.

The report discusses sewage disposal requirements and methods and compares alternative plans for achieving compliance with present discharge requirements and future water quality objectives. It is a basic conclusion of the report that primary treatment followed by deep water discharge represents the most economical method of satisfactorily disposing of dry weather sewage flows.

The sewerage works described in the report are recommended for construction in four stages. Construction costs are estimated at $5.08 million for Stage 1, $3.22 million for Stage 2, and $13.5 million and $19.1 million for Stages 3 and 4 respectively. Stage 1 is required immediately. Subsequent stages will be undertaken only if the need becomes apparent. Based on present information and policy, it appears unlikely that Stages 3 and 4 will ever be required.

In bringing the study to a close, we wish to acknowledge the assistance and cooperation we have received from Mr. Robert Levy, City Engineer, and his staff.

Respectfully submitted,

BROWN AND CALDWELL

Frank J. Kersnar

Dan P. Norris

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CHAPTER 1

INTRODUCTION

During the last 20 years significant and successful efforts have been made to improve the quality of the waters of San Francisco Bay. Through the cooperation of waste dischargers and regulatory agencies the dry weather discharge of raw sewage to the bay has been virtually eliminated, and realization of the full recreational potential of the bay waters is seen as an attainable goal. The rapid population growth and industrial expansion within the San Francisco Bay watershed, however, require continued improvement in waste treatment and disposal systems simply to maintain the present level of water quality. Further enhancement of water quality will require major additional capital outlay.

The problems faced by the City and County of San Francisco in meeting water quality requirements are unique because of the fact that San Francisco is the only community in the bay area that has a combined sewerage system. Despite the problems occasioned by carrying both storm water and sanitary sewage in the same collection system, the city has successfully completed a program of interception which enables the collection and primary treatment of all dry weather sewage flows. Present methods of treatment and disposal are not, however, adequate to meet all of the requirements of the Regional Water Quality Control Board. With respect to future planning, increased dry weather flows and increasingly restrictive disposal policies indicate the need for a thorough review of the city's long-range plans for sewage treatment and disposal.

Objectives and Scope of Study

Recognizing the need for long-range sewerage planning, the city has undertaken a number of studies which will eventually culminate in the preparation of a city-wide sewerage master plan. As a part of this program, the City and County of San Francisco, acting through its Department of Public Works, engaged the firm of Brown and Caldwell to evaluate alternative methods for the satisfactory disposal of the effluent from the city's three sewage treatment plants. Under an agreement dated June 24, 1968, the engineering services to be performed included, but were not limited to, the following:

1. A review of the loadings on the city's three primary treatment plants and the characteristics of the effluents discharged therefrom.

2. A review of the long-range water quality objectives for San Francisco Bay and the Pacific Ocean as established by the State of California's Regional Water Quality Control Board and a determination of the objectives which will be critical with respect to the city's discharges into the bay and ocean.

3. A review of existing reports and information on hydrological and oceanographic conditions in the bay and ocean and determination of the waste receiving capacity of the bay and ocean. Engineering services for field oceanographic surveys were to be undertaken only upon specific written authorization by the Director of Public Works.

4. An evaluation of alternative methods for treatment and disposal of city's discharges in order that the water quality objectives for the bay and ocean can be met. These alternatives were to include, but not necessarily be limited to, the following:

a. Continuing the present discharges and increasing the degree of treatment at each plant as necessary.

b. Continuing the present methods of treatment and conveying the effluents from the plants to the Pacific Ocean for disposal through a deep ocean outfall.

c. Relocating the points of discharge to more favorable locations in the vicinity of the plants and increasing the degree of treatment as necessary.

5. Preparation of estimates of construction and total annual costs for each of the alternatives investigated, including a comparison of the alternatives.

6. Preparation of a final detailed report containing all pertinent background data, descriptions of alternatives, and cost estimates and drawings. The report was specified to be typewritten for duplication by offset printing, with fifty copies furnished to the Director of Public Works.

The scope of this investigation, as defined by the agreement, is confined to the study of disposal alternatives for the dry weather sewage flow. Other investigations are proceeding simultaneously with the evaluation of alternatives for handling wet weather flows.

Information and Data Available to the Survey

The basic data and background information for the study were made available by the City and County of San Francisco. These included design data for the present sewage treatment plants and outfall sewers, records of plant operating costs and operating efficiencies, information on both present and projected future values for dry weather sewage flows and characteristics, and maps of the existing sewerage system.

Measurements of elevation and distance were made on U. S. Geological Survey topographic maps, 7-1/2-minute series, with a scale of 1" = 2000'. General oceanographic information, including water depths and bottom profiles, was

obtained from the U. S. Coast and Geodetic Survey chart of San Francisco Bay entrance, scale 1:40,000. Coast and Geodetic Survey tidal current charts and tables provided reference information on the direction and velocity of tidal currents.

Literature and other references cited by superscript in the text of the report are listed in Appendix A. For simplicity, abbreviations have been used in this report for many technical and nontechnical terms. Each abbreviation which is not in common usage is defined where it first appears.

The long-awaited report on the Bay-Delta Water Quality Plan had not been released at the time this report was prepared, but preliminary copies were made available to the public shortly before this report was printed. A brief discussion of the relationship between the recommendations of this report and those of the Bay-Delta Water Quality Plan is presented in Appendix C.

Acknowledgments

Successful completion of a study of this type is dependent upon the advice and cooperation of many people. We are particularly indebted to Robert Levy, City Engineer, and to Alan O. Friedland and L. A. Vagadori for their direction, advice and assistance.

CHAPTER 2

EXISTING TREATMENT AND DISPOSAL FACILITIES

The first sewers were constructed in San Francisco about the year 1850, and thereafter the sewerage system was rapidly expanded to serve the entire city. Until 1938, when the first sewage treatment plant was constructed, all sewage was discharged raw directly into the bay and ocean. Although completion of the North Point and Southeast sewage treatment plants in 1951 provided sufficient treatment capacity to serve the entire city during dry weather, it was not until 1966 that the final diversions were made to deliver all of the dry weather sewage flow to the treatment plants.

Sewage Collection System

In common with many cities that developed their sewerage systems during the 19th century, San Francisco is served by a system of combined sewers. The term "combined sewers" refers to the combined use of a single system of conduits for conveying both sanitary sewage and storm runoff from the city streets. Since the runoff from a major storm may cause rates of flow in the sewers which are more than 100 times as great as normal dry weather sewage flows, a combined sewerage system quite obviously creates some special problems with respect to adequate treatment and disposal. The solution which the city has adopted provides for the interception, conveyance and treatment of sewage flows up to three times the average dry weather flow. Flows in excess of that amount are bypassed directly to the receiving waters.

While both the design of the collection system and the treatment and disposal of wet weather flows are beyond the scope of this report, each is a facet of the total problem. No single phase of the sewerage problem can be considered entirely independently of the other phases.

Sewage Treatment and Disposal

The entire city of San Francisco is divided into three sewerage service areas, each of which is served by a primary treatment plant. For the purpose of this report the names of the sewage treatment plants also identify the drainage areas they serve. The three plants are known as the Richmond-Sunset, North Point, and Southeast Water Pollution Control Plants. The location of each of the plants, together with the approximate area it serves, is shown on Fig. 2-1. Each of the three plants is described briefly below. The plant descriptions include all modifications to the treatment and disposal works which were under contract at the time this report was written. Other modifications which were in the planning stage but for which contracts had not been awarded are not included in the descriptions.

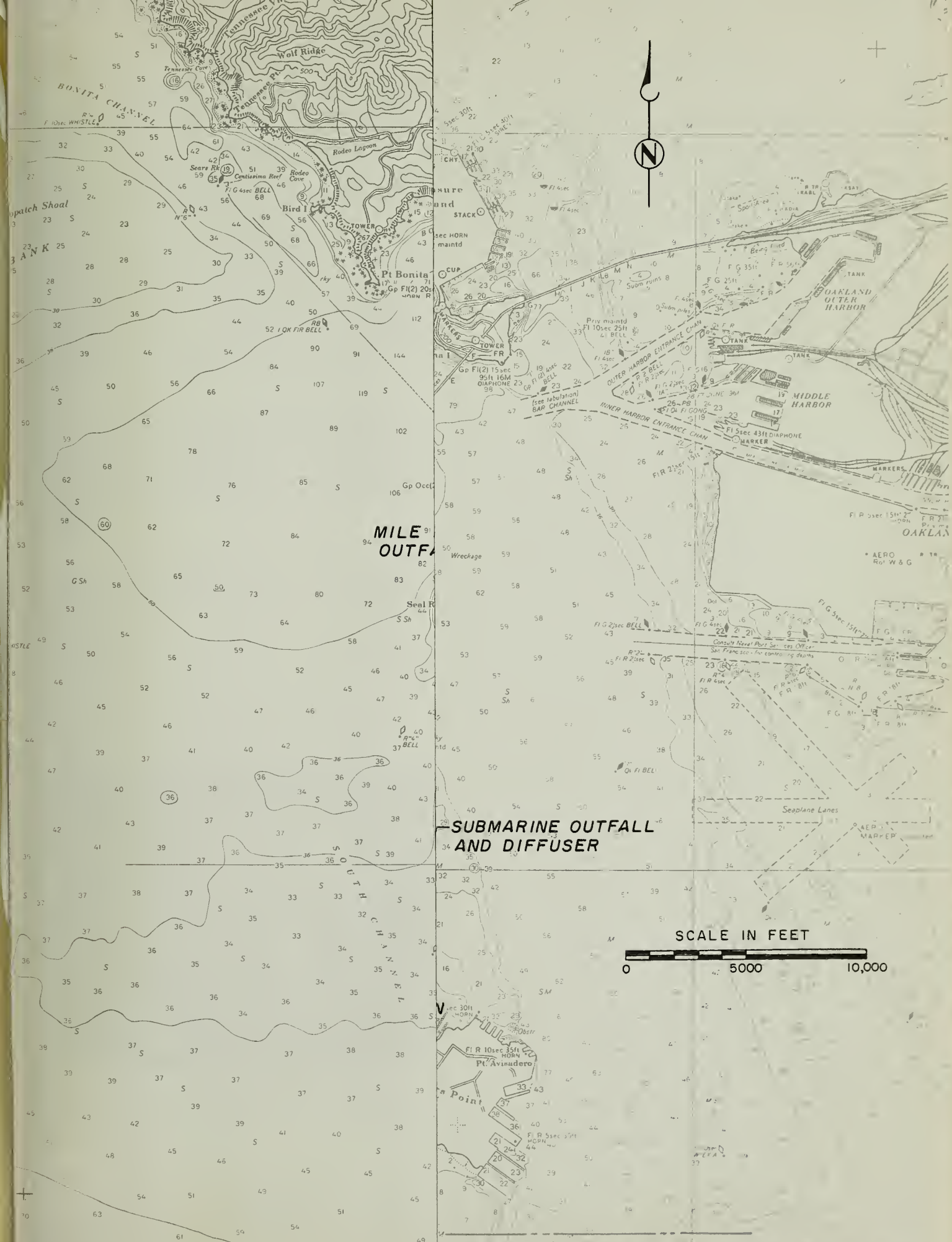

Fig. 2-1. Existing Sewage Treatment and Disposal Facilities

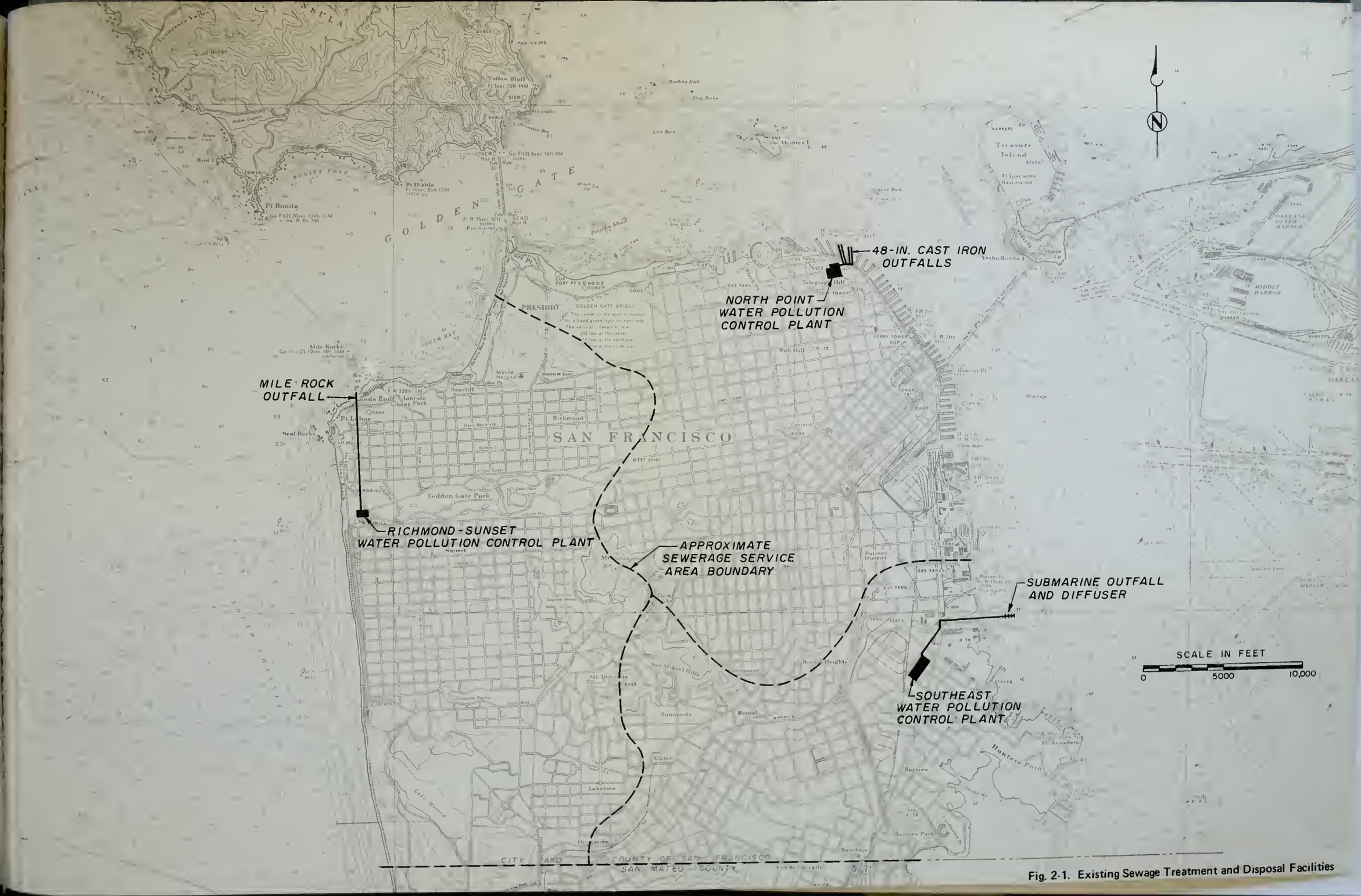

Fig. 2-1. Existing Sewage Treatment and Disposal Facilities

Richmond-Sunset Plant. The Richmond-Sunset water pollution control plant was the first of the city's three plants, and now serves the entire western slope of the city. Situated in the western end of Golden Gate Park, the plant has a peak hydraulic capacity of 70 mgd (million gallons per day) and presently treats an average dry weather flow of about 20 mgd. First constructed in 1938, and subsequently expanded to its present capacity, the Richmond-Sunset plant is a primary treatment plant of conventional design. The principal treatment units include four grit and grease removal tanks with a detention time of about seven minutes at present average dry weather flow, five sedimentation tanks with a detention time of two hours and an overflow rate of 900 gpd/sq ft (gallons per day per square foot) at average dry weather flow, and two sludge digesters with a total capacity of 424,000 cu ft. At present dry weather flows, the plant is operating at a BOD (biochemical oxygen demand) removal efficiency of 37 percent and a suspended solids removal efficiency of 62 percent.

Chlorinated effluent from the Richmond-Sunset water pollution control plant is discharged to the 9 ft by 11 ft Mile Rock outfall sewer, which tunnels under Fort Miley and Lincon Park and discharges to the beach at Lands End about 1.3 ft below mean lower low water. During wet weather the Mile Rock outfall also carries untreated storm water from combined sewers within the Richmond-Sunset drainage area.

North Point Plant. As indicated on Fig. 2-1, the North Point water pollution control plant serves the main downtown section of San Francisco. Completed in 1951, the plant is situated on Bay Street between the foot of Telegraph Hill and the Embarcadero. Peak hydraulic capacity of the plant is 150 mgd, and it is presently operating at an average dry weather flow rate of 57 mgd. Principal treatment units include manually and mechanically cleaned bar screens in series, four grit removal channels, an influent pumping station with a total installed pumping capacity of 190 mgd, and six preaeration-sedimentation tanks with a detention time of 2.8 hours and an overflow rate of 1100 gpd/sq ft at present dry weather flow rates. Sludge and scum removed by the sedimentation process are not further processed at the North Point plant, but instead are pumped through a 10-inch force main to the Southeast water pollution control plant for digestion and disposal. The North Point plant is presently operating at an excellent BOD removal efficiency of 39 percent and suspended solids removal efficiency of 64 percent, based on dry weather flows.

DISCHARGE from the Richmond-Sunset water pollution control plant is visible in the ocean near Lands End.

After chlorination the effluent from the North Point plant is conveyed to four 48-inch cast-iron effluent lines, two of which are laid beneath Pier 33 and two beneath Pier 35. The lines terminate without diffusers about 800 ft offshore

EFFLUENT from the North Point water pollution control plant discolors the water of the bay east of Aquatic Park.

and 10 ft below mean lower low water. Normally, the cast-iron effluent lines carry only treated plant effluent. Storm water is bypassed to the bay at other points.

Southeast Plant. The Southeast water pollution control plant, which went into operation in 1951, is perhaps best considered as two separate plants constructed side by side. The first section of the plant provides conventional primary treatment for the sewage flow from the Southeast drainage area as shown on Fig. 2-1. The second section of the plant consists of the sludge digestion and processing facilities, which handle not only the sludge from the Southeast plant itself but also the sludge transferred from the North Point plant. The two sections are located side by side in the industrial area south of Islais Creek channel and between Third Street and the Southern Pacific right-of-way.

The primary treatment facilities at the Southeast plant are designed for a peak flow rate of 70 mgd, about twice the present maximum dry weather flow. Dry weather flow presently averages 18 mgd. The principal treatment units include hand cleaned and mechanically cleaned bar screens in series, two grit removal channels, an influent pumping station with an installed capacity of 70 mgd, and four preaeration-sedimentation tanks with a total detention time of 4.6 hours and an overflow rate of 630 gpd/sq ft at average dry weather flow. Raw sludge from the sedimentation tanks is pumped to the adjacent sludge digesting and processing plant. Despite the fact that the primary treatment facilities are very lightly loaded in terms of detention time and overflow rate, plant efficiency is only fair. During periods of dry weather the plant removes 28 percent of the BOD and 55 percent of the suspended solids in the raw sewage on the average. These low efficiencies are caused primarily by the carryover of solids from the sludge processing plant.

Raw sludge from both the Southeast plant and the North Point plant is pumped to the sludge processing section of the Southeast plant. There the sludge passes through sludge thickening tanks and the thickened sludge is transferred to digestion tanks. The plant contains 10 digestion tanks with an aggregate capacity of 2.4 million cubic feet, about twice the capacity that is presently needed. The digested sludge is elutriated, conditioned with ferric chloride, and dewatered on vacuum filters. The filter cake, along with grit and screenings from primary treatment, is hauled to sanitary land fill.

After chlorination, plant effluent flows to a pumping station on the south side of Islais Creek. From this point the effluent may either flow by gravity or be pumped to a submarine outfall which extends about 800 ft offshore of the Army Street terminal. A 300-ft long diffuser section located at a depth of about 40 ft below mean lower low water is designed to provide a minimum dilution of 200 to 1 at any point more than 200 ft from the diffuser.

CHAPTER 3

SEWAGE DISPOSAL REQUIREMENTS AND METHODS

Each time a community undertakes the obligation to provide sewage service for its residents, it assumes the attending obligation to dispose of the sewage in a manner which will protect the public health, prevent nuisance in the vicinity of the disposal area, and maintain receiving water quality consistent with beneficial uses. These conditions determine the degree and often the type of treatment which must be provided prior to disposal and strongly influence the selection of a disposal point. Disposal requirements can strongly affect the relative economy and in some cases the feasibility of alternative sewerage projects.

GOVERNMENTAL REQUIREMENTS AND POLICY

Disposal of sewage and industrial wastes is regulated in California by regional water quality control boards. There are nine such boards in the state, each of which is responsible for establishing sewage disposal requirements and water quality objectives within its own topographic region. The San Francisco area is under the jurisdiction of Regional Water Quality Control Board No. 2, with headquarters in Oakland. Although the regional boards act as coordinators with respect to the interests of all local and state agencies, the state and local departments of public health retain special powers with respect to contamination of water involving a significant hazard to public health.

Under the terms of the Federal Water Pollution Control Act, each state must adopt water quality objectives applicable to interstate waters within the state and set forth a plan for the implementation and enforcement of those objectives. If the adopted objectives are not satisfactory to the Water Pollution Control Administration, the latter agency will promulgate its own water quality standards for the interstate waters. At the time this report was written, objectives for interstate waters had been adopted by the state but had not been accepted by the federal agency. The submission was made by the state under protest with respect to the inclusion of tidal waters within the Golden Gate as interstate waters.

Protection of Public Health

Disastrous human experience has amply demonstrated that sanitary sewage constitutes one of the primary vehicles of infection. It follows, therefore, that proper collection and safe disposal of this waste are essential to the protection of public health. The potential hazard to public health is judged and measured by (a) the proximity to sources of human waste discharges, either continuous, intermittent,

or accidental, and (b) the number of coliform group organisms present in the water, usually expressed as the MPN (most probable number) per 100 milliliters. Members of this group, though generally not pathogenic or disease-producing, are present in immense numbers in the fecal discharges of all warm-blooded animals, including man. Since this group as a whole is readily cultured and identified, these organisms are a useful indicator of the potential presence of pathogenic bacteria of sewage origin.

In the case of waters used for recreational purposes, very little evidence is available which relates the degree of coliform contamination to the incidence of water-borne disease. As a result, standards of governmental agencies pertaining to water-contact sports are far from consistent, ranging in limits from an MPN of 240 to 2400 per 100 ml. Further, these are variously expressed as the arithmetic mean, median, or geometric mean of a series of samples, or in some cases as the maximum for a single sample. It is evident, therefore, that a specific coliform limit does not define a line between a safe and a hazardous water, but rather is intended as a desirable and, presumably, attainable goal. The California Administrative Code, Title 17, Public Health, states that for salt waters the bacteriological limit for public beaches and water-contact sports areas is an MPN of 1000 per 100 ml or less in 80 percent of the samples analyzed.

Sanitary provisions applying to waters where shellfish are taken for human consumption are considerably more restrictive than those for recreational areas. Shellfish act as efficient concentration mechanisms for bacteria and certain other contaminants, such as radioactive wastes, and numerous disease outbreaks have been traced to the consumption of raw shellfish grown in polluted waters. The U.S. Public Health Service[1] has established a bacteriological standard calling for a median MPN of not more than 70 per 100 ml for approved commercial shellfish growing areas. It is well established that shellfish from waters meeting this standard will not be involved in the spread of disease which can be attributed to initial contamination of the shellfish, provided that the growing area is also protected against chance contamination with fecal material. Standards for commercial shellfish growing areas are frequently applied as well to areas which are to be protected for sport shellfishing.

Protection of Beneficial Uses

Beneficial water uses which must be protected in providing for waste disposal are ordinarily listed in approximate order of priority. For any given area this order depends on legal decisions, local economic values, and the extent to which the beneficial uses might be damaged by a waste discharge. While disposal of treated sewage by dilution in tidal waters is itself a beneficial use of these waters, it is no longer regarded as a use to be protected to the detriment of other uses. Nevertheless, waste disposal is not necessarily incompatible with other uses. The beneficial uses described below are those uses of the bay and ocean adjacent to San Francisco that the Water Quality Control Board has declared its intention to protect, either as a matter of present policy or as a goal of future policy.

Industrial Water Supply. The waters of San Francisco Bay which are subject to quality impairment as a result of San Francisco waste discharges are used extensively for industrial purposes. For many industries, particularly along the eastern shoreline, the bay serves as the principal source of industrial cooling water.

Recreational Use. Unquestionably, the waters of the Pacific Ocean and of San Francisco Bay adjacent to San Francisco constitute one of the city's most valuable recreational assets. The extent of recreational use was defined in a report to the Regional Water Quality Control Board, prepared by the Board's staff and dated October 30, 1968, which states in part, "Almost all of the City and County's 30 miles of waterfront are used for recreation and esthetic enjoyment. There are 5.5 miles of continuous beach along the ocean and other beaches at Lincoln Park, the Presidio, and Marina and Aquatic Parks. There are five marinas in the city. They are located at Marina Park, in the China Basin channel, and adjacent to Mission Rock. There are also two boat launching ramps near Mission Rock. Fishermen use almost all of the shoreline from which they are not physically excluded. They are excluded from only a few piers and two shipyards. Even then the servicemen and employees fish at Hunters Point. They also fish from boats at several locations along the city's bay shore."

To preserve waters for recreational use, waste disposal must be accomplished without impairment of physical appearance, production of odors, or creation of a public health hazard. Of these, physical appearance relates to turbidity and discoloration, the presence of unsightly solids, or the presence of an oil or grease film on the water surface. Odor production usually results from the discharge of a waste which exceeds the dilution capacity of the receiving water. Bacterial contamination, of course, may be present in the absence of any visual evidence of sewage and thus may well be the greatest hazard.

Fishing and Fish Propogation. Throughout every season of the year the waters of the Pacific Ocean and of the bay adjacent to San Francisco serve either as a habitat or as a migration route for literally millions of striped bass, king and silver salmon, steelheads, and other sport fish. The shallow areas of San Francisco Bay and its estuaries are a natural habitat for shellfish, and the bay at one time supported a thriving commercial oyster industry. Over the years, however, sewage discharges have contaminated the growing areas to the point where shellfish within San Francisco Bay are no longer recognized as fit for human consumption.

Effective fish propogation requires a water environment not only in which fish will survive, but also in which there is an abundance of food material in the form of smaller fish, crustacea, and plankton. The primary criterion for survival of the most popular game fish, such as steelhead and salmon, is that the dissolved oxygen content of the water be maintained continuously in excess of 5 mg/l. So long as adequate oxygen resources are maintained, the discharge of sewage to a marine environment can, within limits, favor fish propogation by reason of the nutrients made available to the food chain organisms.

The recognition and protection of shellfishing as a beneficial use places more stringent requirements on waste disposal to a marine environment than does

any other presently recognized beneficial use. The restrictive bacteriological requirements for waters to be protected for shellfishing place this beneficial use in most cases beyond the scope of present water quality objectives for San Francisco Bay. Nevertheless, it may be expected that as present objectives are attained attention will be turned to the protection of shellfishing in certain appropriate areas.

Other Beneficial Uses. Other beneficial uses listed for the receiving waters adjacent to the City and County of San Francisco include waterfowl habitat, navigation, and esthetic appeal. In general, the nature of these uses is such that they will be protected if the beneficial uses previously described are protected.

Present Requirements for Disposal to Central Bay

The Regional Water Quality Control Board has established discharge requirements for each of the city's three treatment plants. More recently, the Board has adopted a set of requirements governing discharge from the East Bay Municipal Utility District treatment plant in Oakland. These requirements are also pertinent to San Francisco discharges because they define in the light of present policy the conditions for discharge of primary effluent through a deep water outfall to the waters of central San Francisco Bay. In general, all of these requirements define specific limitations both with respect to the quality of the treated waste discharge (effluent requirements) and to the quality of the receiving water affected by the discharge (receiving water requirements). The latter carry the greatest weight; that is, certain effluent quality limitations may be exceeded as long as corresponding receiving water quality requirements are met.

Receiving Water Requirements. Summarized briefly, the discharge requirements state that the waste discharge shall not cause any of the following manifestations in the receiving waters: Floating material, scum, or foam; discoloration beyond the immediate vicinity of the discharge; atmospheric odors; bottom deposits; abnormal algal growths; or conditions which are toxic to aquatic life. As defined in Resolution 68-8, governing the discharge by East Bay MUD, toxic conditions are to be controlled by diluting the waste to 10 percent or less of the 96-hour TLm of the waste as discharged. The symbol TLm is used to denote median tolerance limit, which is a measure of toxicity to test fishes under laboratory conditions. Median tolerance limit is defined as the waste concentration at which half of the test fish die in the stated time.

Other receiving water characteristics to be maintained at all times except in the immediate vicinity of the discharge point include a minimum dissolved oxygen level of 5.0 mg/l (milligrams per liter), a pH between 7.0 and 8.5, and an MPN suitable for water-contact sports as defined in Title 17 of the California Administrative Code.

Effluent Requirements. So long as the receiving water requirements set forth above are being met, the additional requirements on the effluent are minimal. It is required only that the settleable matter not exceed 0.5 ml/l/hr (milliliters per liter per hour). If the receiving water dissolved oxygen requirement is not met, the

effluent must in addition exhibit a BOD removal of at least 90 percent. If the receiving water bacterial quality is not met, the effluent must be disinfected to a level equivalent to that required for the receiving water.

Long-Range Policy

In addition to its regulatory powers, each regional water quality control board is charged with the responsibility for formulating and adopting long-range plans and policy for water quality control within its region. With respect to long-range plans, the State Water Resources Board has recently completed a comprehensive study of water quality control of the Sacramento-San Joaquin Delta and San Francisco Bay. The results of that study, better known as the Bay-Delta Program, were not available at the time this report was written. The Bay-Delta Program will, however, exert a major influence on all future sewerage planning within the San Francisco Bay area.

Present planning objectives of the State Water Resources Board for water quality control in the areas affected by San Francisco discharges are set forth in two policy statements which were prepared by the San Francisco Bay Regional Board and adopted by the State Board. The first, identified as Resolution 67-25, establishes water quality control policy for the Pacific Ocean from Pescadero Point to the mouth of Tomales Bay. The second, Resolution 67-30, establishes water quality control policy for the tidal waters inland from the Golden Gate within the San Francisco Bay Region.

Objectives for Pacific Ocean. Quality objectives for ocean waters vary depending on whether the area under consideration is nearshore or offshore, whether the bottom is sandy or rocky, and whether kelp beds are present or absent. Nearshore waters are defined as those ocean waters between the shoreline at two feet below mean lower low water and 1000 ft. seaward. The distance may be extended further offshore to encompass water contact recreational areas. Offshore waters are all ocean waters seaward of nearshore waters as defined above.

In general, water quality objectives are less stringent in areas where the bottom is sandy and where kelp beds are absent. Quite naturally, objectives are also less stringent for offshore waters than for nearshore waters. The ocean area most readily available to San Francisco for waste disposal, directly to the west of the city, has a sandy bottom without kelp beds. Keeping these facts in mind, the policy statements which will strongly influence plans for ocean disposal of wastes by the city of San Francisco are summarized below.

1. No policy objective has been established for bacteriological quality of offshore waters.

2. The bacteriological quality objective for nearshore waters is an MPN of 1000 per 100 ml or less in 80 percent of the samples, except that in areas to be protected for the taking of shellfish the median MPN for samples collected at the beach is 70 per 100 ml.

3. Dissolved oxygen shall be maintained at a mean annual value of not less than 6.0 mg/l, and no single value shall be less than 5.0 mg/l.

4. All other water quality indicators such as salinity, turbidity, odor, color, bottom deposits, and biotic growths shall not exhibit significant variation beyond the normal limits due to natural causes. In this context a significant variation is one which adversely and unreasonably affects beneficial water uses.

5. Water quality objectives will generally apply at the outer limit of the rising waste plume, in the case of a submerged discharge, or beyond a limited dilution area as determined by the Regional Water Quality Control Board on a case-by-case basis.

6. Toxic or deleterious substances shall not be present in concentrations which adversely affect any beneficial use or which render fish or wildlife unfit for human consumption.

Objectives for San Francisco Bay. Those portions of the water quality control policy for San Francisco Bay which are of special significance in sewage disposal planning are summarized below.

1. Waste dispersion and assimilation is recognized as a use which will be permitted to the extent that it does not objectionably or unreasonably interfere with beneficial uses to be protected.

2. The bacteriological quality objective for bay waters is an MPN of 1000 per 100 ml in 80 percent or more of the samples tested at any point where the water is accessible to the public and suitable for water-contact recreation. This policy objective will be applicable to virtually the entire waterfront of the city of San Francisco.

3. The Water Quality Control Board considers that dilution areas are not fixed and are subject to constant review, with the ultimate objective of their complete elimination or substantial reduction in size.

4. The Board encourages waste dischargers to investigate the advantages of deep water outfalls.

5. Waste discharges shall not cause the dissolved oxygen level in the waters of the bay to fall below 5 mg/l.

6. Turbidity, color, temperature, bottom deposits, and odors in the receiving waters shall not exhibit significant variation beyond the normal limits due to natural causes.

7. Toxic or deleterious substances shall not be present in concentrations which adversely affect any beneficial use or which render fish or wildlife unfit for human consumption.

DEEP WATER SEWAGE DISPOSAL

The capacity of a marine environment to accept sewage and render it harmless depends on its ability to dilute, disperse, destroy, or otherwise reduce the concentration of sewage-borne organisms, and to oxidize and therefore stabilize the entering organic matter. The extent to which these functions can be performed depends on the quantity and composition of the sewage, the current and dispersion characteristics of the receiving water, and the manner in which the waste is introduced into the receiving waters.

Before considering the suitability of specific deep water disposal points, it is well to review the mechanisms which control water quality when a waste is discharged through a submarine outfall sewer. These are four in number: (1) the initial dilution which takes place as the sewage rises to the surface, (2) subsequent dilution after the sewage reaches the surface, (3) the disappearance or reduction of coliform organisms, and (4) the behavior of local currents. While none of these four factors is subject to precise analysis, results of technical studies made elsewhere for similar purposes may be used for evaluating the first three. Local current behavior, however, depends on a number of oceanographic factors which may vary widely from place to place. In each case, therefore, final selection of a deep water disposal point should be based on a thorough study of the oceanography of the site, including field observations where necessary.

Initial Dilution

For clarity, initial dilution has been divided into two phases, (1) the dilution which takes place as a result of energy dissipation of the initial jet velocity and (2) the dilution which occurs as a result of the natural current and turbulence conditions.

When sewage effluent is discharged below the surface of sea water, it is immediately subject to a buoyant force proportional to the difference in density between the sewage and the surrounding salt water. This force tends to bend a horizontal discharge toward the surface and accelerates its ascent. Because of the relative motion between the discharged sewage jet and the sea water, turbulence is generated and mixing takes place. Under proper conditions of discharge velocity and diffuser characteristics relative to current behavior, it is possible to obtain a 40 to 1 dilution of the effluent with sea water at a distance of 10 to 15 feet above the discharge point.

Experimental data and relationships for computing this phase of initial dilution were developed by Rawn and Palmer and were further analyzed and updated by Rawn et al.[2] Using the curves shown on Fig. 3-1, it is possible to estimate the dilution in a rising column for various outfall situations. It is believed that this relationship of dilution to diffuser port diameter and initial jet velocity for various heights above the point of discharge holds until a dilution ratio of approximately 40 to 1 is reached. When this dilution obtains, the effects of turbulence from natural current movement begin to take precedence in the mixing process.

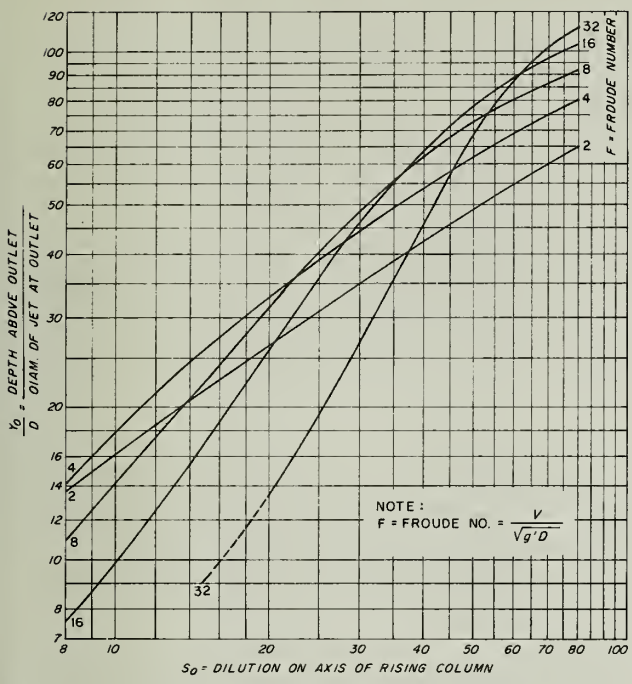

Fig. 3-1. Initial Dilution of Sewage Discharged Horizontally from a Submerged Orifice

The degree of further mixing occurring between this point and the surface can be estimated using an approximate relationship proposed by Whitt.[3] This formula was developed for relating required diffuser length (Ld) with current speed (Sc), depth of discharge (d), quantity of discharge (Q), and additional dilution required to produce the required dilution at the surface (Ad), and is written as follows:

$$Ld = \frac{K\,(Ad)}{Hm\,(Sc)}$$

where K = A coefficient related to differences in mixing efficiency due to variable port diameters and spacing.

Ad = Additional dilution required after 40:1 is reached.

Hm = Height above diffuser between point where 40:1 is reached and surface.

Sc = Current speed which is greater than the lowest anticipated at least 90 percent of the time.

Using the results from the above relationships, it is possible to predict dilutions of sewage effluent with sea water for various diffuser characteristics and oceanographic variables.

Under favorable conditions of temperature-density-stratification and additional dilution, it is often possible to achieve a density of the mixture slightly greater than that of the surface layer of sea water. In such cases, the mixture will either remain below the surface of the receiving body and continue to spread and disperse, or will be carried to the surface under the action of kinetic energy residing in the rising mixture, subsequently to plunge below the surface. Submergence or resubmergence of the mixture results from the discharge of sewage into sea water at a depth where the density is slightly higher than that of the surface water.

Comparisons of mixture densities and initial dilutions for other similar areas indicate that an initial dilution of approximately 100:1 is required before field submergence can be expected. If field submergence does not occur, the sewage-sea water mixture will rise to the surface and spread out as part of the surface layer.

Subsequent Dilution

After reaching equilibrium with its surroundings, whether submerged or in the

surface layers, the sewage-sea water mixture is subject to further mixing action. Subsequent dilution takes place by means of turbulent diffusion into the sea water. Except in extreme cases where strong vertical currents or turbulence exist, such as in an estuary mouth, diffusion is likely to be much greater in the horizontal direction than in the vertical. Hence, the area of the field of diluting effluent increases at a much more rapid rate than does its thickness. Compared with the initial dilution attained in rising from the point of discharge to the surface, subsequent dilution by turbulent diffusion is apt to be relatively slow. Mathematical techniques developed by Brooks[4] were used for estimating subsequent dilution and are equated as follows:

$$C_1 = \frac{E}{L^{4/3}}$$

where E is the coefficient of eddy diffusion in sq ft per hr, C_1 is a constant of proportionality for eddy diffusivity, and L is the width of the sewage field in feet, measured normal to the direction of prevailing current at a particular time after discharge. The proper solution of this equation is dependent on a knowledgeable selection of the coefficient of eddy diffusion, E.

Coefficients of eddy diffusion can be accurately determined by measuring the dispersion of a conservative tracer such as fluorescent dye. Such techniques are routinely employed in the investigation of submarine disposal sites but were beyond the scope of this study. Nevertheless, recent oceanographic investigations of coastal waters adjacent to Marin County, described by Brown and Caldwell,[5] provide information which is adequate for an approximation of eddy diffusion rates in the area around the mouth of San Francisco Bay. As there reported, a total of seven measurements were made of E, the coefficient of eddy diffusion, at points along the western shore of Bolinas Mesa, in Bolinas Bay near the mouth of Bolinas Lagoon, and in Rodeo Cove along the western side of the Bonita Channel. Values of C_1 computed from the measured values of E and L ranged from a low of 18 to a high of 110 ft $^{2/3}$ per hr. From these results it was concluded that a value of 30 is appropriate for C_1 in areas of high current velocities and intense vertical mixing such as occur in the Golden Gate and in adjacent waters on both the bay and ocean sides.

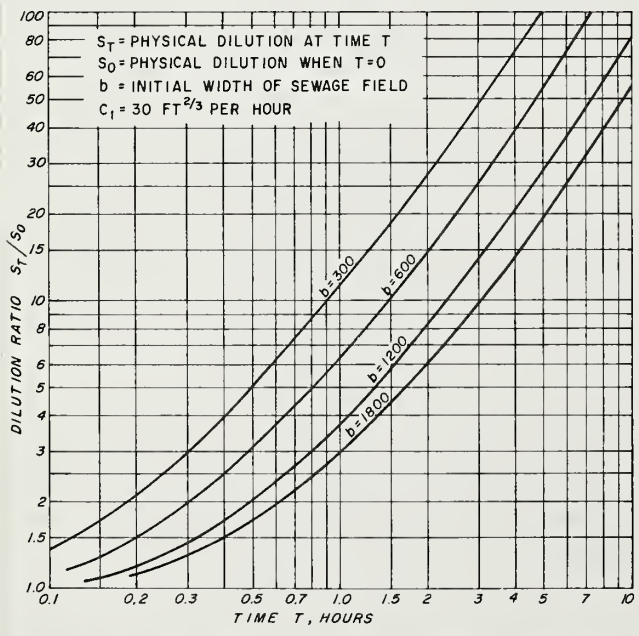

Fig. 3-2. Physical Dilution of a Sewage Field by Turbulent Diffusion

For any value of eddy diffusion, the Brooks formula[4] can be used to express subsequent dilution as a function of time and initial width of the sewage field. The family of curves shown in Fig. 3-2 was developed from the Brooks formula for a coefficient of eddy diffusivity of 30 and was used in this study for calculations of subsequent dilution.

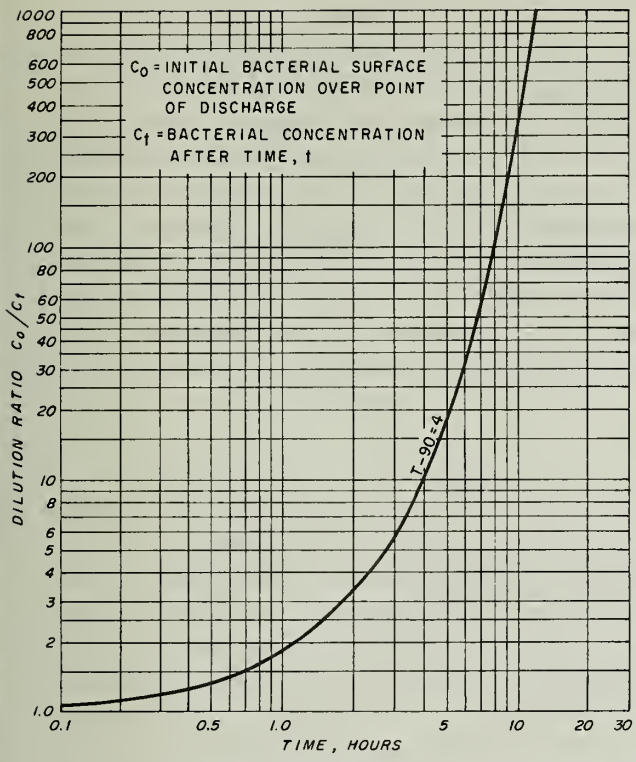

Fig. 3-3. Apparent Dilution Ratio Due to Decline of Sewage Bacteria

Reduction of Coliform Organisms

Although dilution is the primary factor in reducing coliform organism concentrations in sewage discharged from a diffuser, coliforms are also diminished by (1) bactericidal action of the sea water, (2) consumption by protozoans and other small animals, (3) sedimentation and absorption in the receiving water and (4) normal biological mortality or die-off.[6]

Any test designed to measure true bacterial concentrations subsequent to discharge into a receiving water must therefore measure a combination of dilution and disappearance. For this reason it is difficult to devise a means of comparison between observed oceanographic conditions and measured bacterial concentrations. Where adequate oceanographic data are available, a satisfactory answer can be obtained for subsequent dilution. In addition, to arrive at an answer for the rate of total coliform reduction per unit of time, the effect of the above four items must be estimated as a whole.

As employed herein, the rate of coliform bacteria disappearance, T-90, is defined as the time required for a 90 percent reduction in coliform concentration due to the combined effect of all factors except physical dilution. Normally, the disappearance rate is assumed to be constant for any given body of water. Hyperion Engineers, in a 1957 report to the City of Los Angeles,[7] quoted a number of references in which T-90 for bacterial decline exclusive of the effects of physical dilution varied from 2 to 4.8 hours under actual field conditions. The San Francisco Bay-Delta Water Quality Control Program adopted a value of 4 hrs for T-90 in its study of submarine outfalls off the coast of San Mateo County,[8] and the same value appears to be appropriate for the purposes of this study. The curve shown in Fig. 3-3, prepared using a formula developed by Brooks, represents the apparent dilution due to bacterial decline for a T-90 value of 4 hrs.

The most economical deep water outfall design is therefore one in which proper consideration is given to each of the interrelated factors described above: initial dilution, subsequent dilution, and reduction of coliform organisms.

DISPOSAL TO THE PACIFIC OCEAN

There is abundant evidence to indicate that sewage can be satisfactorily disposed of through submarine discharge to the Pacific Ocean after primary treat-

ment. The most recent confirmation of the satisfactory performance of submarine outfalls is presented in the San Francisco Bay-Delta Water Quality Control Program final report on oceanographic studies.[8] After investigating three major Southern California outfalls at San Diego, Whites Point, and Hyperion, which carry average flows of 80, 360, and 350 mgd respectively, the report concluded that comparable design criteria are suitable for the discharge of wastes anticipated under the Bay-Delta Program. While neither the oceanographic conditions nor the discharge conditions for the city of San Francisco are comparable to those for the Bay - Delta Program or for the Southern California outfalls, the basic conclusion remains that a submarine outfall sewer, properly designed and constructed, can adequately dispose of a sewage effluent which has received primary treatment.

Oceanography

As a practical matter, the ocean area which is available to the city of San Francisco for disposal of sewage lies outside the Golden Gate and west of the Richmond-Sunset Districts. The oceanographic characteristics of the entire area are strongly influenced by the tidal ebb and flow through the Golden Gate. The ocean bottom throughout the area is flat to gently sloping and predominantly sandy. Water depths are relatively shallow, generally not in excess of 100 ft within ten miles of the shoreline. On a radius of about five miles from the mouth of the Golden Gate, a semicircular bar a mile or two in width has built up, reducing water depths to 25 to 35 ft. To the westward the main ship channel is dredged through the bar to a depth of 50 ft and a width of half a mile.

By far the major factor influencing currents in the area is the tidal ebb and flow through the Golden Gate. Other factors such as wind and nearshore current patterns may exert a minor effect on currents, but will be of negligible importance to this study. Current direction is generally radial to the mouth of the Golden Gate on both ebb and flood, with maximum velocities in excess of two knots. In the area south of the main shipping channel there is a predominance of ebb currents over flood currents, which results in a net seaward displacement of water with each tidal cycle.

Mixing and dispersion characteristics of the area within the Golden Gate and extending westward to the bar are excellent. As described by the U.S. Corps of Engineers in a 1963 report,[9] "The whole Golden Gate area, from about one mile inside the bridge to four miles outside the bridge, is subject to violent swirls, eddies, whirlpools, and boils." While the intense horizontal and vertical mixing which result from the tidal ebb and flow through the Golden Gate provide superior dispersion and diffusion, they also undoubtedly prevent stratification and the formation of a density gradient which would result in submergence or resubmergence of the effluent field. Effluent disposal to the area inside the bar must therefore be predicated on the assumption that the effluent will rise to the surface and disperse as a surface field.

Disposal Site Evaluation

As a test of the adequacy of the disposal area described above, a trial analysis was made for an outfall discharging the total estimated dry weather sewage

flow from the city of San Francisco in the year 2000. The assumptions on which this trial analysis were based are listed below.

1. The average dry weather flow will be 135 mgd and will be discharged after primary treatment.

2. The flow will be discharged through a 1400-ft diffuser located at a depth of 80 ft. The center of the effluent field will lie 6000 ft west of Seal Rocks.

3. Currents on the ebbing tide will carry the effluent field away from shore, and only the flood tide condition must be considered for compliance with water quality objectives.

4. Chlorination at a rate of 15 mg/l will produce a primary effluent with a median MPN of 10,000 per 100 ml or less.

5. Initial dilution in the rising waste plume will be not less than 50 to 1. A carefully designed diffuser will attain an initial dilution of 100 to 1 or better.

6. Subsequent dilution and coliform die-off will be in accordance with Figs. 3-2 and 3-3.

7. Average current speed in the main channel at maximum flood will be 2.5 knots, equal to 2.9 miles per hour. The shoreward vector of current speed will be less than 1 mph.

Under the assumed conditions, the effluent field at maximum flood would travel from the diffuser location to the Golden Gate Bridge in 1.4 hours. Referring to Figs. 3-2 and 3-3, it will be seen that the dilution ratio due to turbulent diffusion in 1.4 hours is 5, and the apparent dilution due to coliform disappearance is 2.3. The MPN in the effluent field as it passes under the bridge will be the MPN of the undiluted effluent divided by the product of the initial dilution, the subsequent dilution, and the coliform disappearance. This calculation shows that the most concentrated part of the effluent field as it passes under the Golden Gate Bridge would have an MPN of less than 20. This is for all practical purposes an undetectable quantity, and it must be concluded that a discharge of the type assumed would not exert a measurable influence on the waters of San Francisco Bay.

Having determined that the trial discharge would not affect the waters of San Francisco Bay, the next step is to determine whether it would exert an adverse effect on the shoreline westward of the Golden Gate Bridge. As pointed out earlier, currents on an ebbing tide will carry the effluent field away from shore, and the field should therefore have no effect at all on the ocean beaches south of Seal Rocks. When the tide is flooding, however, the effluent field will be carried toward Phelan Beach and Bakers Beach. The rate of shoreward travel of the effluent field, however, will be much slower than the rate of movement parallel to the shore. Investigation of a comparable condition at Rodeo Cove in 1966[5] showed the median rate of shoreward travel over the last 1500 ft to the beach to be 12 fpm (feet per minute), with a maximum value of 21.5 fpm, or about 0.25 mph. For the purposes of this

trial analysis, a conservative value of 1 mph was assumed. Since the nearest beach is two miles from the discharge point, the minimum time of travel would be two hours, and the dilution achieved, which is a function of time, would be even greater than that calculated at the point of entrance into the bay.

Though further investigation on this point may be warranted, it may be initially concluded that there is no possibility for the development of bottom sludge deposits at the site under discussion. The suggested site lies near the mouth of the Golden Gate, where an equilibrium condition exists between deposition and the scouring action of the strong tidal currents. As evidenced by the bottom topography, normal deposition of the silts carried out of the bay takes place along the bar several miles to the west of the disposal site. Settleable solids contained in the sewage effluent, widely dispersed and probably no longer identifiable, could be expected to follow a similar pattern of deposition.

All of the factors discussed above lead to the conclusion that the area west of Seal Rocks is well suited to the innocuous submarine disposal of sewage after primary treatment. While an intensive investigation of the site, such as is normally carried out in the process of outfall design, may reveal conditions which are either more or less favorable than assumed in this analysis, it is expected that all such findings can be compensated for in the final design of the outfall system.

DISPOSAL TO SAN FRANCISCO BAY

The North Point and the Southeast water pollution control plants presently discharge primary effluent to San Francisco Bay. In the past both plants have from time to time experienced difficulty in meeting disposal requirements, particularly those pertaining to physical appearance and bacteriological quality of the receiving waters. More recently, the North Point plant has demonstrated to the satisfaction of the water quality control board that it is capable of disinfecting the primary effluent to a degree sufficient to maintain water-contact sports bacterial quality in the effluent. Improvements now under construction at the Southeast plant should result in the production of an effluent of comparable quality. Disposal to San Francisco Bay, however, cannot be discussed solely in the context of the individual discharger, but must consider as well the cumulative effect of all wastes discharged to the bay system, both present and future. The approach adopted for this study involved first, the investigation of the cumulative effects of all wastes, including those of San Francisco, on the bay system as a whole, and second, an investigation of the probable local effects of the San Francisco discharges on the environment in the vicinity of the discharge point.

Mathematical Model Studies

Because of the complex and interrelated factors of currents, dispersion, reaeration, and tidal interchange which control waste assimilation in San Francisco Bay, determination of the effect of waste discharges is not amenable to routine techniques of mathematical analysis. Fortunately, however, the San Francisco

Bay-Delta Water Quality Control Program has developed computer techniques which make feasible the analysis of specific water quality problems. The basic tool used in these analyses was the hydraulic-water quality mathematical model of the San Francisco Bay system developed by Water Resources Engineers, Inc., one of the contracting firms on the Bay-Delta Program. A review of the mathematical bay model indicated that it would provide valuable information on future water quality conditions in the vicinity of San Francisco and on the effect that San Francisco discharges might have on those water quality conditions. Accordingly, the firm of Water Resources Engineers, Inc. was commissioned to run a computer program on water quality conditions in San Francisco Bay based on the projected future discharges from all dischargers tributary to the bay system.

Model Description. The mathematical model is composed of a network of points (junctions) interconnected by theoretical channels arranged to simulate the hydraulic properties of the bay such as volume, surface area and depth. The model duplicates the hydraulic conditions in the bay by computing the movement of water through the theoretical channels and the corresponding changes in water surface elevation and water volume at the junctions. By solving specific hydraulic equations which describe current movement and tidal action in the bay mathematically, the computer can predict the hydraulic behavior of the bay in terms of tidal elevations, current velocities, and mass movement of water.

Altogether, the mathematical model consists of 350 junctions and 480 channels extending from Sacramento and Stockton on the east to Guadalupe Slough at the south end of the bay. The central bay, extending from Point San Pedro on the north to International Airport on the south, is the area of principal concern to this study. Therefore, a finer grid system was used in the central bay than in the remainder of the bay system, with junction points at an average spacing of about one mile.

The water quality component of the model was designed to represent mathematically the transport of either a conservative pollutant, such as a salt, or a non-conservative pollutant, such as organic matter expressed in terms of its oxygen demand or BOD. The present study was concerned both with BOD and its effect on dissolved oxygen levels and with toxicity, which was represented by a hypothetical conservative pollutant. By computing the transfer which will take place in accordance with the hydraulic properties of the bay, the model can predict the direction and rate of dispersion of a pollutant discharged to the bay at any point. By simultaneously solving the appropriate equations for BOD decline and reaeration rate, the computer can predict the actual concentrations of BOD and dissolved oxygen which are likely to occur at any point and at any tidal stage for a given discharge condition. For this study the computer was also instructed to calculate the proportionate effect on the waters of the bay which is attributable to the wastes discharged by San Francisco.

Program Assumptions. In any mathematical program of the type described herein it is necessary to make certain assumptions in order to make the problems amenable to analysis. Insofar as possible the assumptions used in this program were the same as those adopted for the Bay-Delta Program. The principal assumptions employed are described briefly below.

1. The hydraulic conditions of the model were the same as those employed for the Bay-Delta Program, including summer tidal conditions and an outflow of 3000 cfs from the Delta.

2. All waste loadings on the San Francisco Bay system except those from the city of San Francisco represent the loadings projected for the year 2020 by Department of Water Resources and Bureau of Reclamation for use in the Bay-Delta Program. Waste loadings from the city of San Francisco were developed by assuming primary treatment of the future sewage flows projected by the Department of Public Works for use in this study.

3. Reaeration rate was based on oxygen deficit and surface area. Coefficients were selected to represent the natural surface reaeration processes of the bay. Oxygen added by photosynthetic processes was ignored.

4. Waste loadings were assumed to be continuously applied at the junction point adjacent to the point of waste origin. BOD loadings are discussed in terms of 5-day BOD values, but the model applied the load in terms of ultimate carbonaceous or first-stage oxygen demand.

5. A coefficient of 0.20 was employed in the equations which describe the rate of oxygen uptake in satisfying (or reducing) the BOD.

6. A hypothetical conservative pollutant was used to represent toxicity and was assigned an arbitrary concentration of 1000 mg/l in all municipal and industrial waste streams. Since the computed concentrations are relative only and do not bear any direct relationship to the established toxic content of any waste stream, the word "toxicity" is used in quotation marks when discussing the hypothetical pollutant.

7. An inherent feature of the mathematical model is that any transfer of flow or pollutant from one junction to another is always assumed to be completely dispersed throughout the water volumes represented by the respective junctions. Waste inputs are therefore assumed to be instantaneously dispersed throughout the volume of the input junction.

Program Application. The computer program had two basic objectives: first, to determine the effect of future waste discharges on the water quality of the central bay in the vicinity of San Francisco, and second, to assess the relative effect of future San Francisco waste discharges on receiving water quality. To accomplish these objectives, the program was set up to determine the future concentrations of three critical water quality factors: BOD, dissolved oxygen, and "toxicity". Each of these factors was assessed both with and without the waste inputs from San Francisco. By difference, therefore, it was possible to determine the proportionate effect of San Francisco discharges on each factor. Waste inputs for the city of San Francisco were based on the data presented in Table 4-1 for the year 2000, assuming primary treatment of the waste streams prior to discharge. The program assumes that effluents from both the North Point and Southeast plants are

discharged through submarine diffusers which achieve adequate initial dispersion of the flow within the receiving water mass. The Richmond-Sunset discharge was assumed to have no effect on conditions inside the Golden Gate.

The computer program was run for an equivalent prototype time of 62 tidal cycles of 25 hours each, or about 65 days. By the end of this period the computed BOD and dissolved oxygen concentrations had become stabilized throughout the bay, as indicated by the fact that the same values were repeated for a number of consecutive tidal cycles. Computed values for "toxicity" were approaching steady state conditions in the south and central bay. In the north bay and delta area, where the conservative constituent representing "toxicity" had to travel much farther to reach equilibrium throughout the bay, a steady state condition was not achieved in 62 tidal cycles. However, a review of conditions at that time indicated that discharges from the north bay area will not seriously affect water quality at the points of discharge for the city of San Francisco. The program was therefore terminated at 62 tidal cycles.

Model Results. Perhaps the most significant results of the computer analysis were those related to "toxicity" concentrations. Since each waste stream was assumed to contain a uniform "toxicity" concentration of 1000 mg/l, each 10 mg/l represents a one percent concentration of "toxicity". Therefore, if a concentration of 10 mg/l is computed for a specific location in the bay, it indicates that one percent of the total water mass at that point emanated from a waste discharge at some time or other.

The analysis showed concentrations generally less than 10 mg/l in the central bay west of the San Francisco Bay Bridge and south of Point Richmond (Fig. 3-4). From this area concentrations increased both to the north and to the south until concentrations approaching 100 mg/l were present in Suisun Bay and south of the Dumbarton Bridge. The low concentrations in the central bay are of course a result of the massive dilution and flushing caused by tidal flow through the Golden Gate. Concentrations resulting from San Francisco waste discharges were negligible north of Angel Island and varied from less than one mg/l in the vicinity of the North Point discharge to a maximum value of about three mg/l in the deep water channel east of Hunters Point. Concentrations attributable to San Francisco discharges decreased steadily to the south of Hunters Point, but some residual values were indicated as far south as the Dumbarton Bridge. Throughout the area where significant values were indicated for San Francisco "toxicity", these values averaged 10 percent or less of the total "toxicity" in the receiving waters.

Calculated concentrations of BOD showed the same pattern of dispersion as "toxicity", but since BOD is continuously degraded, the absolute values were far smaller. The maximum concentration computed for any point in the central bay was only slightly over one mg/l, and the maximum value adjacent to a San Francisco discharge point was 0.7 mg/l in the deep water channel offshore of the Southeast plant. The maximum concentration of BOD attributed to the San Francisco discharges was not in excess of 0.16 mg/l at any point.

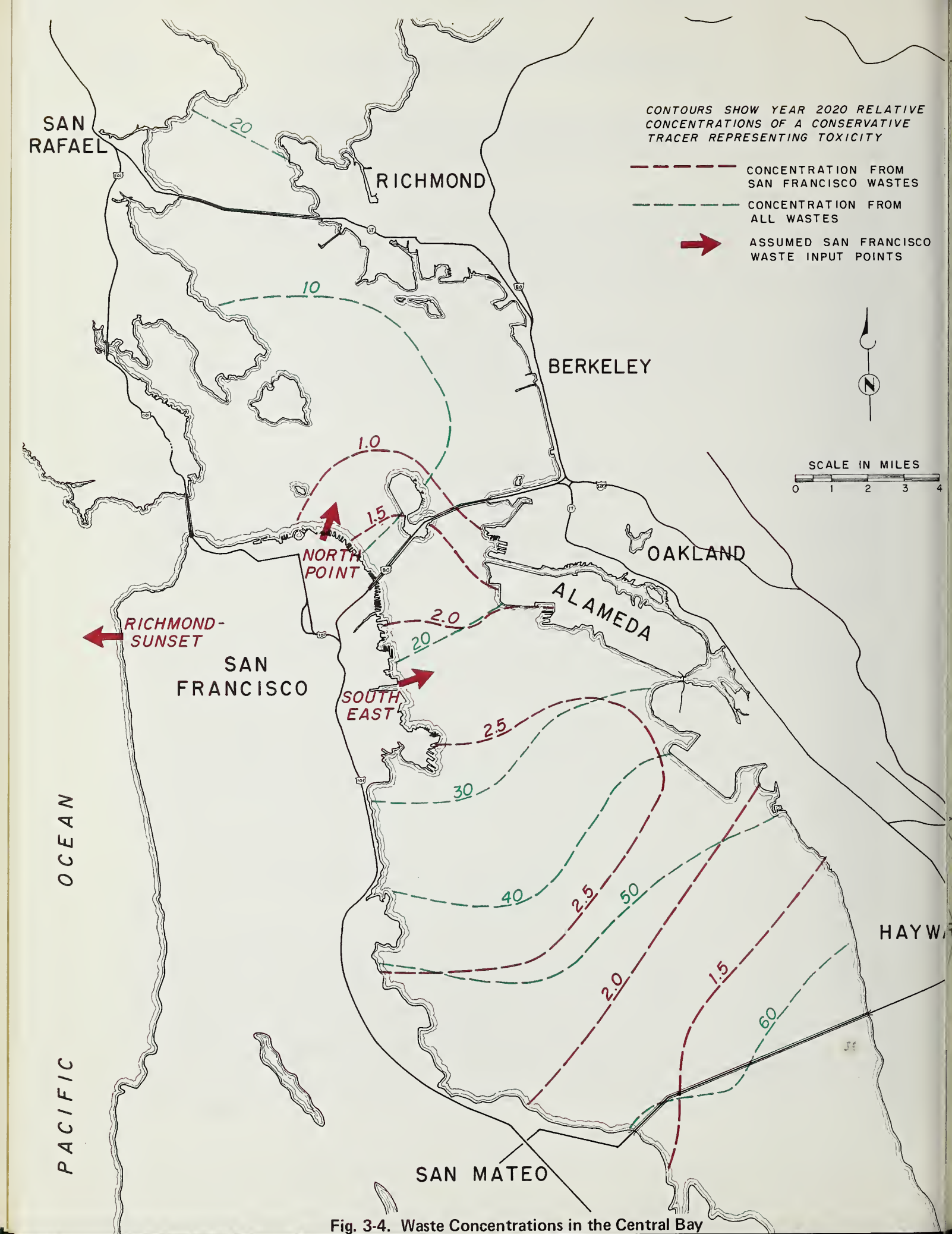

Fig. 3-4. Waste Concentrations in the Central Bay

Dissolved oxygen concentrations are not of primary concern to this study, since their value can be materially influenced by many factors, such as temperature and photosynthesis, which are not amenable to analysis in a program of this type. Discussion is therefore confined to oxygen depletion resulting from the degradation of the waste BOD loadings. Again, the computer program showed the central bay to be in excellent condition, with a maximum oxygen depletion of 0.75 mg/l due to waste loadings. Oxygen depletions generally increased with distance from the Golden Gate, with some tidal reaches such as Guadalupe Slough, the Petaluma and Napa rivers, and various channels in the delta showing substantially complete depletion of dissolved oxygen. The maximum oxygen depletion caused by the San Francisco discharges was 0.07 mg/l in the vicinity of the Southeast plant.

The results of the computer program make it clear that while some areas of the bay system would be seriously degraded by the assumed waste inputs, the central bay west of the San Francisco Bay Bridge would not be adversely affected. Even assuming the continued discharge of primary effluent by the Southeast and North Point plants, the total of all wastes in that area would be diluted in excess of 100 to 1. Considering only the waste discharges from the city of San Francisco, dilution would be on the order of 1000 to 1. Dissolved oxygen depletion in the central bay west of the bridge as a result of all waste inputs would be less than 0.5 mg/l. Receiving water conditions south of the San Francisco Bay Bridge within the sphere of influence of the San Francisco discharges would be of slightly poorer quality than in the North Point area, but with no clear indication that future water quality objectives can not be met. The ability to continue indefinitely the local discharge of primary effluent from the Southeast plant may depend on future policy decisions with regard to water quality criteria and on future technical decisions concerning other major waste discharges to the south bay. It appears, however, that long-range plans for the city of San Francisco should include an alternative for an increased degree of treatment or for a change in discharge point for the Southeast plant.

CHAPTER 4

DESIGN CRITERIA AND BASIS OF COST ESTIMATES

Wherever the costs of alternative projects are to be evaluated, the various projects must be laid out in sufficient detail to permit comparisons of performance and of the costs of construction, operation and maintenance. In order to make valid comparisons, the projects must all have a common basis for design and for the estimation of costs. Prior to laying out the alternative plans, therefore, it is necessary to establish design criteria applicable to all major sewerage facilities and to develop basic cost data for all elements of the several alternative projects.

DESIGN CRITERIA

Design criteria and basic cost data presented herein apply to preliminary design or layout of major sewerage facilities. In layouts of this type, it is necessary only that a reasonably close approximation of the size, location, type of construction, route and cost of the various facilities be developed, and that this information be given in sufficient detail to permit comparisons between alternative plans. Obviously, therefore, relocation and resizing of some of the facilities will be required at a later date as a result of the detailed engineering analysis which is made during the preparation of construction drawings and specifications.

Development of Loading Factors

Since this study is concerned only with the disposal of dry weather sewage flows, records collected at the city's three sewage treatment plants provide an adequate basis for the determination of unit strength and flow factors applicable to present dry weather flows. Future values projected to the year 2000 were furnished by the San Francisco Department of Public Works.

Sewage Flows. As indicated in Table 4-1, average dry weather sewage flow for the city of San Francisco is expected to increase from a present value of 95 mgd to 135 mgd by the year 2000. The greatest increase is projected for the area served by the Southeast plant, where the flow is expected to double. A 40 percent increase is projected for the Richmond-Sunset area and a 25 percent increase for the North Point area.

The future peak flow for the purposes of this study is taken as the peak hydraulic capacity of the existing plants. For each plant this assumption will result in a ratio of peak to average flow in the year 2000 which is about the same or slightly greater than the present ratio.

Table 4-1. Dry Weather Sewage Loading Factors

Factor	Plant			Total
	North Point	Richmond-Sunset	Southeast	
Average daily flow, mgd				
1968	57	20	18	95
2000	71	28	36	135
Peak flow, mgd				
1968	113	44	36	193
2000	150[a]	70[a]	70[a]	290
BOD, pounds per day				
1968	118,000	33,000	43,000	194,000
2000	147,000	46,000	86,000	279,000
Suspended solids, pounds per day				
1968	103,000	34,000	55,000	192,000
2000	128,000	48,000	110,000	286,000

[a] Peak hydraulic capacity of the plant.

Sewage Strength. Present and projected future values for raw sewage strength, expressed in pounds per day of BOD and suspended solids, are presented in Table 4-1. Present values for the North Point and Richmond-Sunset plants represent the average for the six dry weather months from April through September as reported for the years 1965 through 1968. For the Southeast plant, a shorter period of record was used in order to include only those tests which did not show the interfering effect of solids recycling within the plant.

Since past records of sewage strength have shown little change with time, it was assumed that future values will remain unchanged. The future values expressed in pounds per day were therefore projected on the same ratio as the increase in sewage flow.

Trunk Sewers and Force Mains

Where trunk sewers or force mains were used to convey sewage flows from the present plants to alternative points of disposal, the design flow was taken as the future peak dry weather flow shown in Table 4-1. Trunk sewers were laid out to provide a minimum velocity of two feet per second when flowing full, and force mains were sized to provide velocities which will prevent the deposition of solids in the pipes. Capacities were determined by means of Manning's pipe friction formula using a roughness coefficient "n" of 0.013. Gravity sewers were assumed to be constructed of reinforced concrete with rubber ring joints. For force mains, the pipe was assumed to be cement lined and coated steel with welded joints.

Pumping Stations

As in the case of the sewers and force mains, the design capacity of pumping stations was selected from the future peak dry weather flow values shown in Table 4-1. For each pumping station the number of pumping units installed is sufficient to pump the design flow with one unit out of service. All pumping units are equipped with variable speed drives to minimize wet well size and reduce possible odor problems.

For pumping raw sewage the pumping units are assumed to be centrifugal sewage pumps with a maximum head capability of 120 feet. For heads greater than this value, the standard centrifugal pumps are employed in pairs, so arranged that one pump discharges into the suction of the second. For pumping primary effluent it is assumed that the greatly reduced quantities of solids in the flow will permit the use of pumps with smaller clearances which are capable of attaining a maximum head of 140 feet, or 280 feet when two-stage pumping is employed.

The pumping station superstructure normally is constructed of reinforced concrete or masonry and is designed to blend architecturally with the surrounding area. Standby engine drives or standby power units are provided in cases where bypassing cannot be allowed or where line storage cannot accommodate flow during temporary power outages. Design of pumping stations provides for complete separation of wet and dry wells with easy access to both and includes automatic control equipment, metering devices, adequate ventilation to prevent condensation on walls and equipment, and all other necessary appurtenances.

Sewage Treatment Plants

Primary considerations in the design of a sewage treatment plant are the required capacity and the degree of treatment. Plant capacity is usually expressed in terms of average dry weather flow, with peak hydraulic capacity given as an upper limiting value. The degree of treatment is based on the strength and quantity of the sewage in relation to the capacity of the receiving waters. A plant must be designed with sufficient capacity to handle peak organic as well as peak hydraulic loads, and where appropriate must be planned for enlargement to handle future increases. Except in unusual cases where an exceptionally pure effluent is required the treatment requirements can normally be met by primary treatment, followed if necessary by some form of secondary treatment.

Primary treatment removes readily settleable solids and floating material. Plant processes include screening, grit removal, sedimentation, and sludge treatment and disposal. At design loadings, sedimentation units in plants handling predominantly domestic sewage generally provide for two hours detention and remove almost all of the settleable solids, 30 to 35 percent of the BOD, and about 50 to 60 percent of the suspended solids. Slightly higher removals may be expected at flows less than the design value and correspondingly lower removals at flows greater than design. In cases where the plant effluent is to be disposed of through a properly designed ocean outfall sewer, the sedimentation period is sometimes cut to as little as one hour at design flow.

Secondary treatment usually embodies some form of biologic treatment for further reduction of the suspended solids and BOD. One of the most effective biologic processes, and the one which requires the least land area, is the activated sludge process. Activated sludge plants provide secondary treatment by mixing primary effluent with a biologically active floc. The organisms which make up the activated sludge floc require oxygen for their metabolic process and this is supplied by aerating the mixture. In the usual type of municipal activated sludge plant, blowers are used to introduce air into the mixture through diffusers located near the bottom of relatively long and narrow aeration tanks. Effluent from the aeration stage passes through a final sedimentation tank and the readily settleable floc is returned to the aeration unit to maintain a high concentration of activated sludge. The degree of treatment offered by the activated sludge process is higher than any other economically competitive process. With loads of 30-50 pounds of BOD per 100 pounds of active sludge solids, BOD removals in the range of 85 to 90 percent may be obtained. Higher removals may be obtained at lower loading rates. Assuming reasonable care in operation, the activated sludge process produces no offensive odors and requires less isolation than other processes. The activated sludge process was considered for all secondary treatment applications in this study.

All treatment processes provide for the separate collection, digestion and disposal of primary and secondary sludge. Sludge digestion tanks which are properly heated and stirred may be designed for a loading rate of 0.15 pounds of dry solids per cubic foot daily. It is assumed that the present practice of digested sludge disposal by sludge dewatering and sanitary land fill will be continued in the future.

Disinfection of sewage is normally attained by chlorination of the effluent. The amount of chlorine and the contact time required depend on the degree of prior treatment, the initial rapidity of mixing the chlorine with the effluent, the design of the contact chamber to avoid short circuiting, and, of course, the degree of disinfection required.

The additional treatment facilities which are considered in this report will be of top quality in appearance and function. This implies that the treatment units are laid out to provide flexibility in operation and control. Protection against complete plant shutdown is provided by bypasses around each major unit, and insofar as practicable, multiple process units are provided. Their design also includes adequate illumination and ventilation, convenient means for drainage of plant units, provisions for health and safety of personnel and for accessibility to and ease of operation and maintenance of gates, control valves, and other operating devices. Adequate measurement, sampling, laboratory, and maintenance facilities, alarm devices, and automated controls are included to the extent required for reliability of operation and as justified by reduction in operating costs. Provision is made for odor prevention and control, both in basic design and, as necessary, through special structures and equipment for that purpose. Special attention is given to appearance through architectural design of basic layout, buildings and process structures, and landscaping.

Submarine Outfalls

Submarine outfalls are designed to carry the future peak dry weather flow from the plants they serve and to provide for diffusion of the waste stream into the receiving waters by means of multiple outlet ports. Diffuser sections are designed in accordance with the basic principles set forth in Chapter 3 to achieve the required degree of dilution considering such factors as depth of water, current speed, and, of course, receiving water requirements.

Materials for submarine outfall lines are taken as either reinforced concrete or lined and coated steel pipe. All outfalls are provided with a firm foundation and a suitable anchorage, and are designed to permit periodic cleaning and flushing as found necessary by operating experience. Specific details of design, anchorage, or construction methods require extensive investigation of local conditions and are beyond the scope of this report.

CONSTRUCTION COSTS

As stated previously, construction costs in this report are based on preliminary layouts of the proposed sewerage improvements. For estimating purposes, prices of comparable work were obtained from available sources of current information. Manufacturers, suppliers of material and equipment, and local contractors were consulted on specific questions. Costs of pumping stations and sewage treatment plants as derived from actual projects designed by the firm of Brown and Caldwell were relied upon heavily but were adjusted to local conditions. Wherever possible, use was made of actual costs of sewerage facilities constructed in recent years.

In considering the estimates, it is important to realize that changes during final design will alter the totals to some degree, and that future changes in the cost of material, labor and equipment will certainly cause comparable changes in costs here presented. On the other hand, since the relative economy of alternative projects can be expected to change only slightly with an increase or decrease in general construction costs, decisions based on present comparisons should remain valid.

Construction costs can be expected to undergo long term changes in keeping with corresponding changes in the national economy. The best available barometer of these changes is the Engineering News-Record (ENR) construction cost index. It is computed from prices of structural steel, portland cement, lumber, and common labor, and is based on a value of 100 in the year 1913.

As indicated by the curve on Fig. 4-1, which portrays the trend of the ENR index since 1940, nationwide construction costs have been steadily increasing for

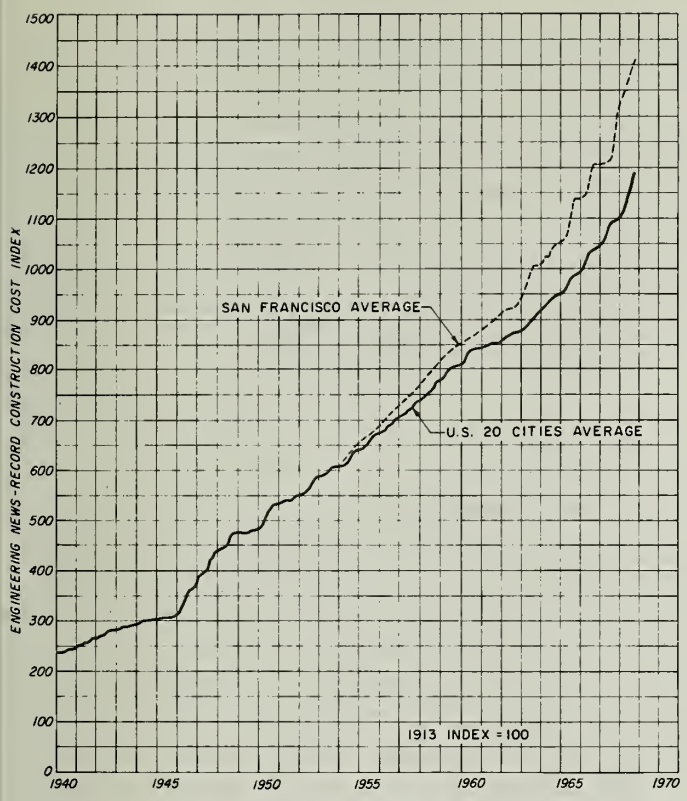

Fig. 4-1. Engineering News-Record Construction Cost Index

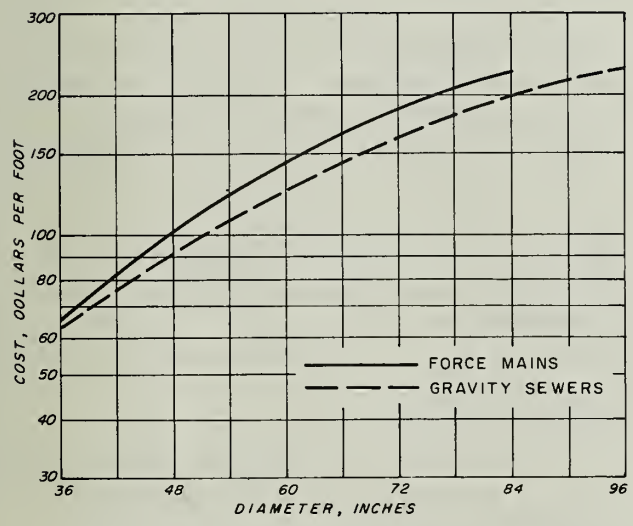

Fig. 4-2. Unit Costs of Force Mains and Gravity Sewers

many years. This figure also shows the rate of increase of the San Francisco area ENR index, which has risen in recent years at a rate considerably more rapid than the average for the country as a whole.

For purposes of this report, estimated costs are based on an ENR index of 1500, a level which is expected to be reached in San Francisco during 1969. In any event, costs presented in this report may be related to those at any time in the past or future by applying the ratio of the then prevailing ENR index to 1500.

Unit prices shown in this chapter include contractor's overhead and profit, but do not include engineering, construction contingencies, rights-of-way, land acquisition or legal costs. Separate allowances have been made to cover these items. It must be pointed out that the unit prices used in preparing preliminary estimates represent average bidding conditions for many projects. For this reason, it is entirely possible that actual construction bids for a given project may be lower or higher than the unit prices used herein. Although additive or deductive items are applied where believed necessary to cover special conditions, the preliminary estimates are not presumed to be as accurate as estimates prepared during final design.

Trunk Sewers and Force Mains

Unit costs for the construction of trunk sewers and force mains represent the cost of laying large pipes in the streets of San Francisco. The unit cost curves (Fig. 4-2) were developed from a review of approximately 40 separate contracts let by

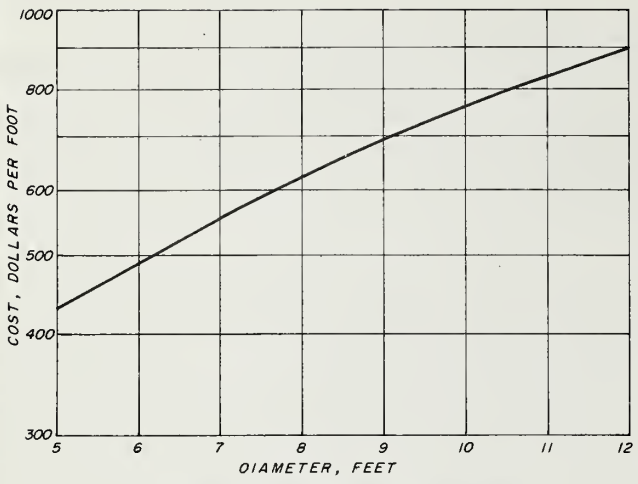

Fig. 4-3. Unit Cost of Tunnels

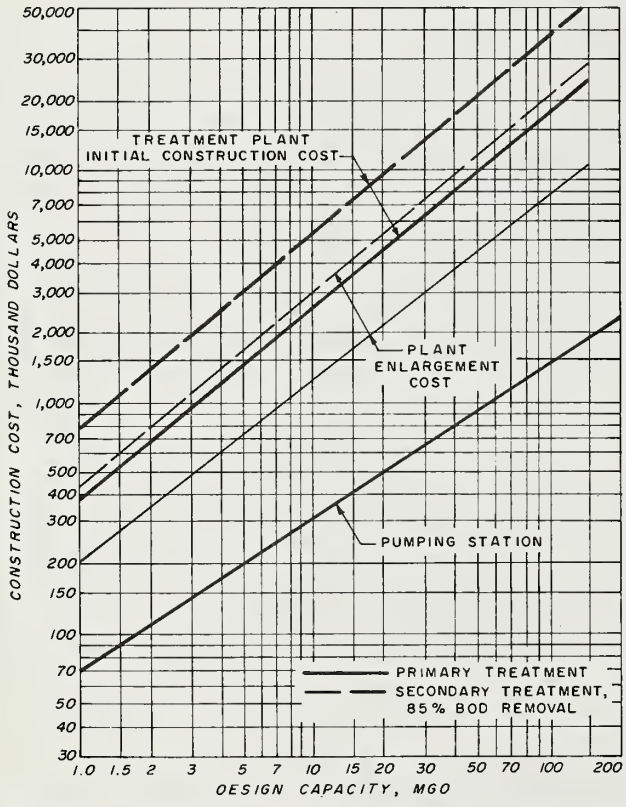

Fig. 4-4. Construction Costs of Sewage Treatment Plants and Pumping Stations

The curves for sewage treatment plants are based on average dry weather flow and include the cost of basic structures, channels, major pipelines and service units necessary for enlargement to twice the initial flow. Enlargement costs provide only for additional treatment units necessary to achieve the desired increase in capacity. Cost of land is not included. Pumping station costs are based on peak wet weather flow.

the Department of Public Works and by the Water Department. The curves, adjusted to an ENR of 1500, represent the cost of installing both gravity and pressure lines in virtually all sections of San Francisco under a wide variety of construction conditions. While local conditions may cause variations from the unit cost curves, it is believed that the curves reasonably represent the average cost of the long pipelines considered in this report.

Tunnels

Tunnel costs (Fig. 4-3) have been derived from a review of a number of west coast tunnels, and are based on an ENR index of 1500. A review of the general geology of the northern San Francisco peninsula indicates that tunneling conditions may be regarded as average to good. The major geologic formation of the area is a group of related rocks of Upper Jurassic age known as the Franciscan formation. Typically, these rocks are soft and heavily weathered and fractured in the surface layers and firmer at depths greater than about 50 feet. There are no major fault zones within the area where tunnels would logically be constructed. Since a detailed geologic investigation of the route is essential to the accurate estimation of tunneling costs, the curve in Fig. 4-3 has been drawn to represent the higher range of the construction costs which may be expected.

Pumping Stations

Costs for pumping stations as shown on Fig. 4-4 are based on peak rates of flow with sufficient pumping capacity to handle peak flows with one pumping unit out of service. The cost curve as shown also reflects the structural, mechanical, electrical, and architectural design cri-

teria previously established. In addition, the curve includes an allowance for full automatic control of pumping functions, and for suitable landscaping and fencing.

The curve represents the cost of a single-stage raw sewage pumping station with a maximum head capability of 120 feet, or a single-stage effluent pumping station with a maximum capability of 140 feet. Where two-stage pumping is required, stations are estimated to cost 150 percent of the comparable single-stage installation. When constructed as an integral part of a sewage treatment plant under a single contract, pumping stations are estimated to cost 75 percent of the amount shown. Treatment plant cost curves include influent pumping.

Sewage Treatment Plants

In developing unit cost curves for sewage treatment plants an extensive analysis of actual unit construction costs for basic plant components was made, and cost curves developed for each type of treatment plant shown. Curves were verified by comparison with construction costs of many treatment plants built since World War II and with published construction cost curves. All curves are exclusive of the cost of land, engineering, and legal services. As here presented (Fig. 4-4) the unit cost curves are representative of average costs in the San Francisco Bay area based upon an ENR construction cost index of 1500. Secondary treatment plant costs have been developed for 85 percent BOD removal utilizing activated sludge.

Treatment plant costs are based on initial construction of units to accommodate a given dry weather flow, with later additions to accommodate twice the initial flow. In addition to sedimentation, aeration and digestion facilities, initial costs provide for inlet structures, channels, major pipelines, control and service facilities, and other basic units which can be used without enlargement when the capacity is increased. Enlargement costs provide for additional sedimentation, aeration, and digestion units necessary to achieve the desired increase in capacity. Enlargement costs are applicable for plant expansion to two or three times the initial design capacity.

In using the curves, it is necessary to allow for the extraordinary design problems associated with such factors as high maximum hydraulic capacity, excessive BOD and suspended solids loading conditions, and special structural and foundation conditions. When these factors are taken into account, the curves provide a useful medium for estimating costs of treatment plants of various capacities.

Ocean Outfall Sewers

Unit costs for ocean outfall sewers (Fig. 4-5) are based upon the evaluation of known costs of submarine outfalls constructed in areas with generally similar oceanographic characteristics to those here considered. The curve reflects costs for outfalls terminating at a moderate depth of less than 200 feet. The cost includes the construction of a straight diffuser section of normal length at the outlet end. Where extensive amounts of rock are encountered at a submarine outfall location, costs will be higher than shown on Fig. 4-5, and each such case has been estimated separately.

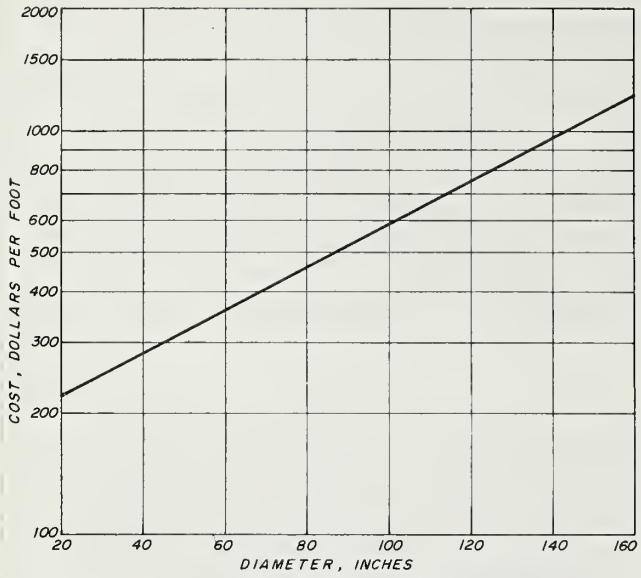

Fig. 4-5. Unit Cost of Submarine Outfall Sewers

Contingencies

Contingent costs are considered in two forms, identified as project contingencies and construction contingencies. Project contingencies allow for the uncertainties unavoidably associated with preliminary design. Such factors as foundation conditions, necessity for special construction methods, and variations in final lengths of pipelines are a few of the many items which may increase contract costs and for which allowances must be made in preliminary estimates. For project contingencies, an allowance of 15 percent is applied to all projects. Construction contingencies amount to 10 percent, and represent the normal allowance for extra work which the city of San Francisco routinely employs on all construction contracts. The total allowance for contingencies in the construction cost estimates presented in this report is therefore the sum of project contingencies and construction contingencies, equivalent to 25 percent of each project.

Engineering Costs

The cost of engineering services for major construction projects may include special investigations, predesign reports, surveys, foundation explorations, location of interfering utilities, detailed design, preparation of contract drawings and specifications, construction inspection, material testing, and final inspection of the completed work. Depending on the size and type of the project, total engineering costs may range from 7 to 15 percent of the contract cost. The lower percentage normally applies to large projects and those which do not require a large amount of preliminary investigation. The higher percentage applies to smaller projects or to those which require a large amount of preliminary investigation. Since the relative size of projects into which the proposed work may be divided cannot be anticipated at this time, engineering costs for the purpose of this report are based on 12 percent of the contract costs. When applied in sequence, construction contingencies and engineering amount to about 40 percent of the basic contract costs. An exception to this rule is the case of submarine outfalls. Because of the unusually high expenses involved in underwater inspection, engineering costs on submarine outfalls normally run about 5 percent higher than for other construction projects of comparable dollar value. All construction cost estimates developed in this report include an allowance of 40 percent for contingencies and engineering on all projects other than submarine outfalls and an allowance of 45 percent for outfalls.

ANNUAL COSTS

Alternative projects are compared not only on a first cost basis, but on an annual cost basis to permit a true economic evaluation. Annual costs take into account operation, maintenance, administration, depreciation, and interest on borrowed capital. When factors other than annual cost are involved, they also must be evaluated before reaching the final decision on which alternative is best.

Interest and Depreciation

Interest rate for municipal bonds has been taken as 4.5 percent. If the current trend continues there may be a period of higher interest rates; however, it is expected that the average interest rate over the amortization period of the major structures will not exceed 4.5 percent. Depreciation was computed by the sinking fund method using 4.5 percent interest. Annual interest and depreciation is commonly referred to as "fixed cost" and may be computed by using the capital recovery factor found in most interest tables.

The economic life of all sewers, force mains and outfalls has been taken as 50 years. In treatment plants and pumping stations, equipment is normally replaced prior to the full depreciation of the structures. This fact was accounted for by amortizing half of the construction cost over a period of 50 years to represent the structure and amortizing the remaining half over a period of 25 years to represent the equipment. Replacement of mechanical equipment is assumed to be due only to obsolescence, inadequacy, or major deterioration. The cost of repair and minor replacements is included under operation and maintenance. The economic life assigned to the various units is only to facilitate cost comparisons and does not necessarily reflect the true useful life. There are many sanitary sewers in service which are more than 50 years old, and some have been in service more than 100 years. The Richmond-Sunset sewage treatment plant, constructed over 30 years ago, still has many years of useful life ahead of it.

Cost of Land

For those treatment plant alternatives which require larger or smaller amounts of land than are presently owned by the city, the purchase or sale of the land, together with its effect on the tax rolls, was considered as an annual cost. The annual cost of land purchases was computed using the capital recovery factor for 50 years at 4.5 percent interest. The annual value of land sales was taken as an annual return of 4.5 percent on the sale price. For property purchased by the city, the annual loss of tax revenue was taken as $10.23 per $100 present assessed valuation. For land sold by the city a corresponding gain in tax revenue was allowed.

Operation and Maintenance

The annual costs of operation and maintenance include all costs for labor, power, supplies, laboratory control and monitoring, administration, and incidental

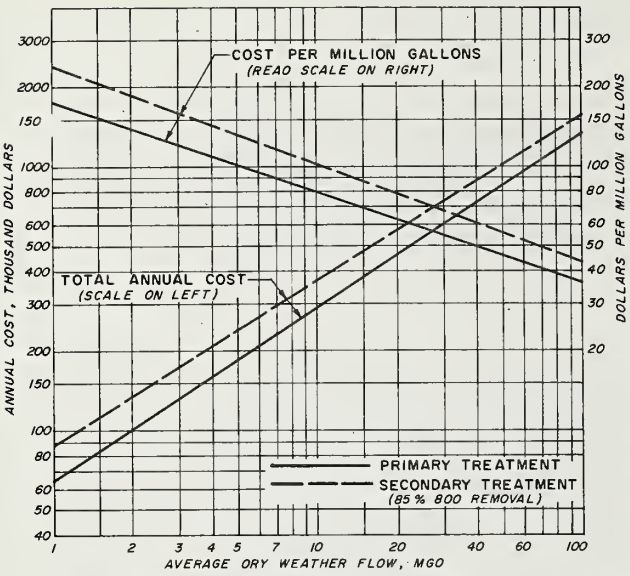

Fig. 4-6. Operating Costs of Sewage Treatment Plants

costs chargeable to the various components of the sewerage system. As with costs for construction, operation and maintenance costs are based on current price levels. Wherever information was available, the costs used in this report were adjusted to reflect recent experience in the city of San Francisco.

Pipelines. The annual operation and maintenance cost for trunk sewers, force mains and submarine outfall sewers was taken as 0.3 percent of the construction cost. This allowance, representing an average value over the economic life, can be expected to vary from year to year. In the case of submarine outfalls, this allowance covers periodic underwater inspection and the removal of accumulated grease and solids as necessary.

Pumping Stations. Maintenance and operating costs for pumping stations are the sum of the power costs for the average dry weather flow and pumping head, and the other costs which are related to the peak flow which the station is designed to accommodate. Power costs are based on Pacific Gas and Electric Company rate schedule No. A-13 and take into account the 20 percent discount which is given to the city of San Francisco. Operation and maintenance costs other than power include labor, supplies, administration, replacement parts and repairs necessary to keep pumping and auxiliary mechanical units in effective operating condition. Together, these costs may be expected to comprise three percent of the construction cost per year.

Sewage Treatment Plants. Operation and maintenance costs for sewage treatment plants (Fig. 4-6) are based on average dry weather flow and have been derived from operating reports of numerous agencies. These costs assume first-class operation and include costs for labor, power, supplies, replacement parts, repairs, administration, effluent monitoring and laboratory control. The curves have been adjusted to current wage and price levels and reflect the actual recorded cost of sewage treatment at the city's three existing plants.

The curves shown in Fig. 4-6 do not include the cost of effluent chlorination, since this rate may vary from plant to plant and for different disposal points and seasons of the year. Effluent chlorination costs are additive to plant operating costs, and are based on a chlorine cost, including application, of 6 cents per pound where the chlorine is furnished in ton containers and 4 cents per pound where the chlorine is furnished in carload lots.

CHAPTER 5

SEWAGE DISPOSAL ALTERNATIVES

Briefly, the report thus far has been concerned primarily with the presentation of background material necessary to the formulation and analysis of various plans for disposal of dry weather sewage flows from the city of San Francisco. In this chapter alternative plans are developed and compared and a long-range program for sewage disposal is recommended.

Degree of Treatment Required

Disposal requirements and water quality criteria are discussed in Chapter 3. From the information presented in that chapter it can be seen that the degree of treatment must be adequate to guarantee that the receiving waters will meet three basic requirements; (1) an acceptable physical appearance, (2) a satisfactory bacteriological quality, and (3) an absence of deleterious toxic or biostimulatory effects. Data are presented in Chapter 3 to demonstrate that an adequate degree of primary treatment, followed by deep water discharge through a submarine diffuser will meet the first two requirements. In this context, an adequate degree of primary treatment means careful removal of floatable solids and scum and removal of settleable solids to a degree sufficient to insure that adequate disinfection can be economically obtained through the application of chlorine. These objectives can normally be accomplished in a primary plant with properly designed screening and skimming equipment and a detention time of 90 minutes based on average dry weather flow.

The basic water quality requirements of acceptable appearance and satisfactory bacteriological quality can also be met by a good quality chlorinated secondary effluent with little or no dilution. In the case of the existing San Francisco plants, it is assumed that after secondary treatment the effluent can be safely discharged through the existing plant outfall lines.

The third basic water quality requirement, relating to toxicity and biostimulation, is not amenable to control by normal treatment processes. In fact, for the city of San Francisco the only apparent economically feasible method of controlling these factors is by the transfer of effluent out of the bay and into the Pacific Ocean. At the present time, this requirement does not pose a problem insofar as the waste discharges from San Francisco are concerned. Control measures will be required in the future only if it is determined that San Francisco waste discharges are having an undesirable toxic or biostimulatory effect on the waters of the bay.

Use of Existing Treatment Plants

Each of the three existing sewage treatment plants in the city of San Francisco is potentially capable of providing a satisfactory degree of primary treatment for the

Table 5-1. Sewage Treatment and Disposal Alternatives

Alternative No.	Description
1	Construct a deep water outfall adjacent to each of the existing plants. Continue primary treatment.
2	Same as 1, but feed polymer to improve the efficiency of primary treatment.
3	Construct a deep water outfall at North Point. Pump Southeast effluent to Richmond-Sunset. Construct deep water outfall for combined Southeast-Richmond-Sunset effluent.
4	Construct a deep water outfall at Southeast plant. Pump North Point effluent to Richmond-Sunset. Construct deep water outfall for combined North Point-Richmond-Sunset effluent.
5	Pump effluent from both Southeast and North Point plants to Richmond-Sunset. Construct deep water outfall for combined effluent of all three plants.
6	Abandon treatment at Southeast and North Point plants and pump raw sewage to Richmond-Sunset. Expand Richmond-Sunset to accommodate total flow. Construct deep water outfall.
7	Construct secondary treatment at each plant site. Discharge through existing outfalls.

projected dry weather flow from its tributary area. In some cases, particularly in the Southeast plant, some relatively minor process modifications will be required. However, in nearly every case these modifications are already in the planning, design, or construction stage. For the purposes of this report it is assumed that each of the existing primary plants will continue to be used without major expansion and that all necessary minor improvements and modifications will be made. The costs associated therewith are not considered in this report. Under the projected future flow conditions it is assumed that each plant will be capable of removing 60 percent of the suspended solids and 30 percent of the BOD from the raw sewage. This is considered to be a conservative assumption and better removals may in fact be obtained.

ALTERNATIVES FOR TREATMENT AND DISPOSAL

A total of seven alternative schemes of sewage disposal (Table 5-1) were developed and analyzed for construction cost and total annual cost. Each alternative is technically feasible and each is capable of meeting the present requirements and stated water quality objectives of the Water Quality Control Board. The alternatives cover a range of treatment efficiency from 30 percent to 85 percent BOD removal and consider ocean disposal of up to 100 percent of the total dry weather flow. Each of the alternatives is described below.

Alternative 1

The first alternative considers deep water disposal of the effluent from each of the city's three plants at a point adjacent to the plant site. Each plant would continue to provide primary treatment. The estimated construction and total annual

costs of Alternative 1 are presented in Table B-1, included in Appendix B. As there indicated, construction cost is estimated at $8.3 million and total annual cost at $3.1 million.

Richmond-Sunset Outfall. The deep water outfall for the Richmond-Sunset treatment plant would be designed to accommodate a flow of 70 mgd, which represents the peak hydraulic capacity of the plant. The outfall would consist of about 5000 ft of 54-in. pipe extending due west of the plant site and terminating in a 600-ft diffuser section located at a depth of 40 ft. Because of the shallow water depth in this area, the outfall and diffuser section are somewhat longer than would otherwise be necessary.

North Point Outfall. The North Point outfall would begin in the vicinity of Piers 33 and 35 and would extend 4000 ft northward to the center of the deep water channel between North Point and Alcatraz. The 78-in. outfall would terminate in a 650-ft diffuser section located at a depth of about 80 ft. Use of the present outfall lines which are laid beneath Piers 33 and 35 would be discontinued.

Southeast Outfall. The Southeast sewage treatment plant has an existing submarine outfall which had been constructed but had not yet been placed in operation when this report was written. The outfall is composed of about 500 ft of 54-in. pipe and a diffuser section of approximately 300 ft located due west of the end of the Army Street terminal at a depth of 40 ft. The performance expected from the diffuser was calculated by Dr. James D. Cumming for J. H. Pomeroy & Co., consultants to the city. Dr. Cumming concluded that even under the least favorable conditions of tide and currents the diffuser is capable of achieving dilutions on the order of 200 to 1 at any distance greater than 200 ft from any diffuser outlet. The city's plans include provisions for future extension of the outfall by 6600 ft, if this is found necessary by operating experience. This extension would move the diffuser section to the middle of the deep water channel between San Francisco and Alameda and increase the water depth at the diffuser to about 55 ft.

The cost estimates presented in this report for the Southeast outfall assume that the outfall will be extended 6600 ft in the future. It should be clearly understood, however, that the present outfall is considered to be adequate for compliance with existing requirements and that the planned extension would be made only if future conditions indicate the need for improved dispersion or if a greater buffer zone is desired between the shoreline and the surfacing effluent field.

Alternative 2

Alternative 2 considers the use of polyelectrolytes as coagulant aids to improve the efficiency of conventional primary treatment. In recent years a large number of coagulant aids of many different types have been placed on the market but most of them have certain common characteristics. Nearly all are long-chain polymers of very high molecular weight which, when applied to a waste stream in minute concentrations, promote the coagulation and settling of the suspended material in the waste stream. This alternative is considered only in conjunction with Alternative 1, but in fact it could also be applied to the other alternatives considered in this report.

Selection of the proper coagulant aid for a particular waste stream is at present strictly a process of trial and error and there is no guarantee that worthwhile results will be obtained in every case. The advantages of the process can, however, be substantial, particularly in those alternatives which employ only primary treatment. Where conventional primary treatment may remove 60 percent of the suspended solids in a waste stream, field trials have shown that the use of coagulant aids can often increase the solids removal to 85 or even 90 percent. The increased solids removal causes a proportionate reduction in BOD, improves the physical appearance of the effluent, and increases the efficiency of chlorination.

To evaluate the cost of this alternative it was necessary to make certain assumptions concerning the use of coagulant aids as follows:

1. The use of a coagulant aid with primary treatment will increase suspended solids removal to 85 percent.

2. The increase in BOD removal will be proportional to the increase in suspended solids removal.

3. The cost of chemicals will be $5.00 per million gallons of sewage flow.

4. The cost of chemical application will be $0.50 per million gallons.

5. No capital investment is required to put a coagulant aid feed program into operation.

Applying these assumptions to the projected future average dry weather flow, it was calculated that the cost of polymer feed would amount to $142,000 per year at the North Point plant, $72,000 per year at the Southeast plant, and $56,000 per year at the Richmond-Sunset plant, for a total cost of $270,000 per year.

Alternative 3

The third alternative for sewage disposal considers exporting the effluent from the Southeast treatment plant to an ocean outfall. Should it be necessary to reduce the volume of San Francisco's waste discharge to the bay, exportation of the effluent from the Southeast plant would be the logical first step for several reasons. First, the Southeast plant flow is the smaller in volume of the two bay discharges and therefore less costly to pump to the ocean. Second, future water quality conditions adjacent to the Southeast plant are likely to be somewhat poorer than comparable conditions adjacent to North Point. Finally, the Southeast plant will receive the greatest total of industrial wastes with the probable result that its toxicity will be greater than the North Point discharge. The Bay-Delta Program has pinpointed toxicity as a water quality factor of special concern.

As indicated in Fig. 5-1, the exportation system would consist of a two-stage pumping station located at the Southeast plant, a force main extending to the lowest point in the peninsula watershed divide at the eastern end of Golden Gate Park, and

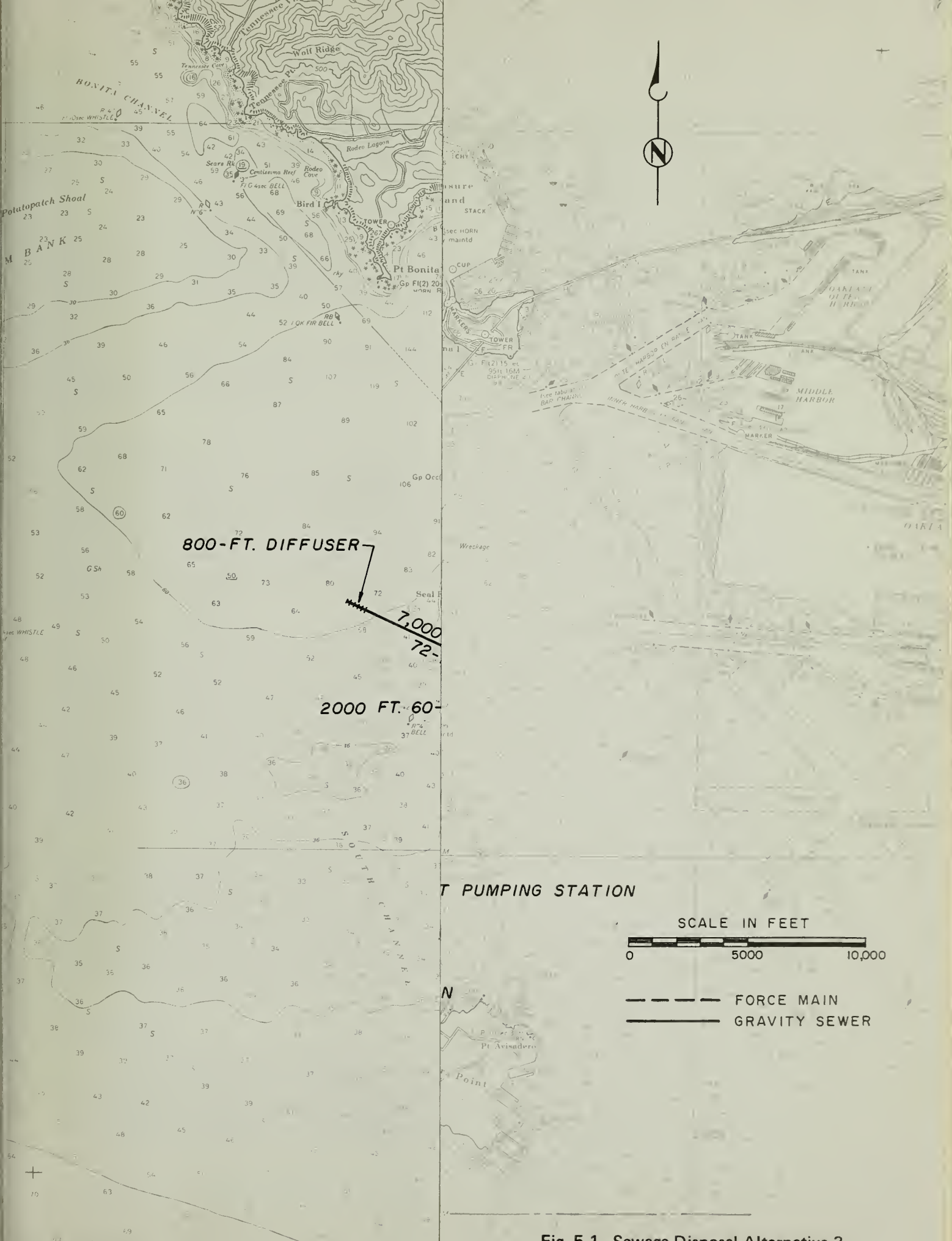

Fig. 5-1. Sewage Disposal Alternative 3

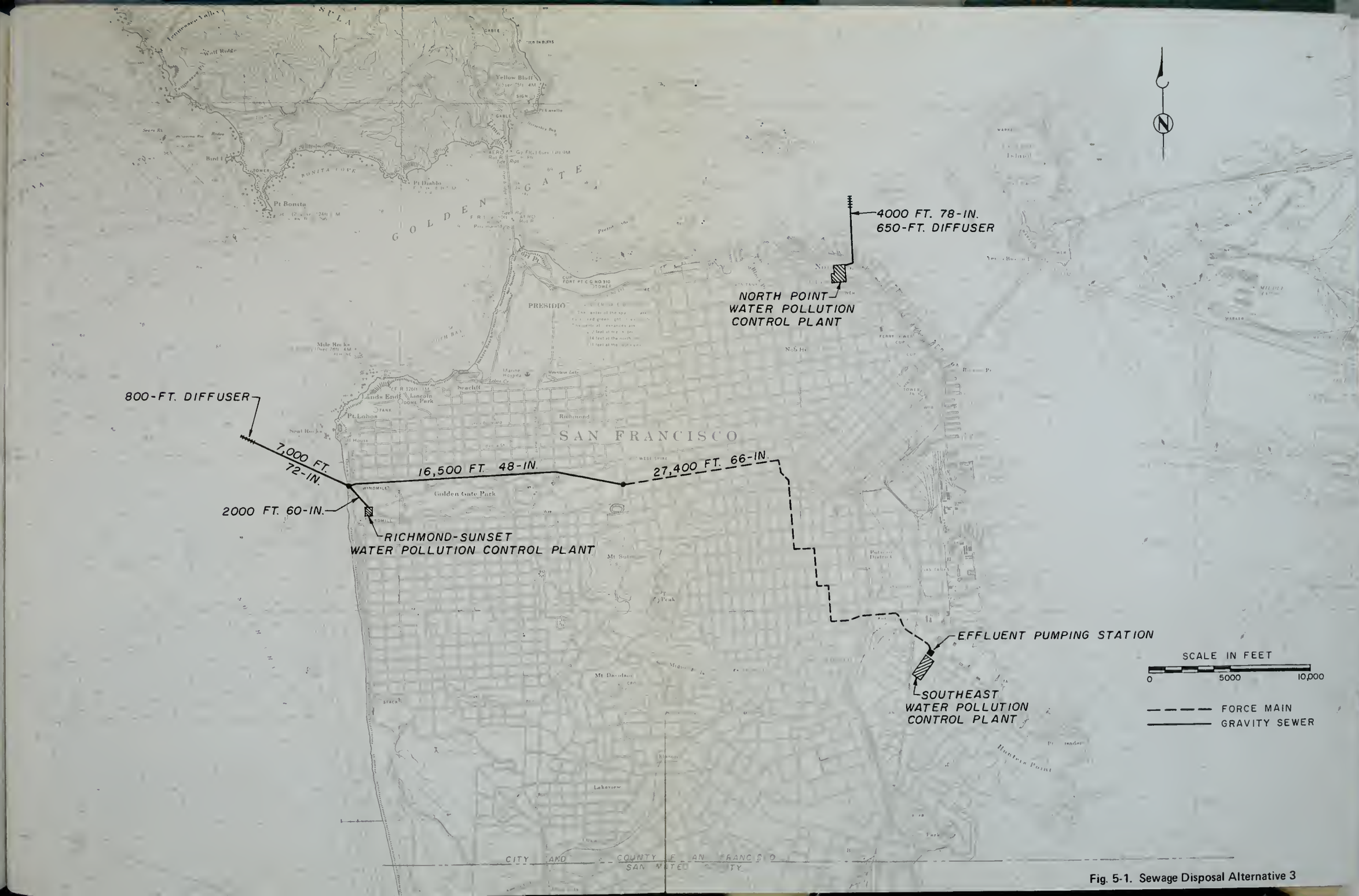

Fig. 5-1. Sewage Disposal Alternative 3

a gravity sewer running westward to the start of the ocean outfall. Investigation of alternative routes for the pipelines, including a route that involved single-stage pumping and a tunnel of minimum length, showed that both the construction and total annual cost are lowest for the route shown.

Under this alternative the ocean outfall would be constructed with a maximum capacity of 140 mgd, sufficient to accommodate the peak flow from both the Southeast and the Richmond-Sunset plants. Because of the increased flow, the outfall would be run northwesterly into the deeper water west of Seal Rocks. The outfall at the North Point plant would be the same as that in Alternative 1.

Construction and total annual costs for Alternative 3 are presented in Table B-2 in Appendix B. Estimated costs are $18.3 million for construction and $3.8 million for total annual cost.

Alternative 4

Alternative 4 considers the exportation of effluent from the North Point plant while continuing to discharge primary effluent at the Southeast plant. The major advantage of this scheme is that it would satisfy the technical objective of nondegradation of the waters of San Francisco Bay. If the North Point discharge were exported to the ocean, then the total San Francisco dry weather waste discharge to the bay would never in the future be as great either in volume or total pollutional load as it is today.

Under Alternative 4 (Fig. 5-2), a two-stage effluent pumping station would be constructed at the North Point plant to transfer the plant effluent to an ocean outfall west of Seal Rocks. Pumping station and line capacity would be 150 mgd, equal to the peak capacity of the North Point plant. As in the case of Alternative 3, routes which involved tunneling to reduce the pumping head were found to be uneconomical, and the flow is therefore pumped over the peninsula at the eastern end of Golden Gate Park. A total of 25,500 ft of 84-in. force main and 16,500 ft of 60-in. gravity sewer is required to convey the flow to the start of the ocean outfall.

The ocean outfall would have a capacity of 225 mgd, equal to the peak hydraulic capacity of both the North Point and Richmond-Sunset plants, and would extend 8000 ft into the ocean west of Seal Rocks, terminating at a depth of about 70 ft. This alternative assumes that the Southeast outfall to the bay would be extended as described in Alternative 1. As detailed in Table B-3 (Appendix B), the construction cost of Alternative 4 is estimated to be $24.1 million, and the total annual cost $4.3 million.

Alternative 5

It is worthwhile to consider, at least from the standpoint of comparative costs, an alternative which would exclude all dry weather sewage discharges from San Francisco Bay. While present requirements and policy do not indicate the need for such extreme measures, it is possible that future policy changes could either pro-

hibit discharge to the bay or require such a high degree of treatment that exportation would be the most economical alternative. Alternative 5 (Fig. 5-3) considers exportation of the primary effluent from both the North Point and Southeast plants. The routing of force mains and gravity sewers is the same as shown for Alternatives 3 and 4. The ocean outfall is also shown in the same location as in previous alternatives, but would be extended to a depth of about 80 ft. A 1400-ft diffuser section would be employed to disperse the peak design flow of 290 mgd. Construction cost for Alternative 5 is estimated at $31.1 million, and total annual cost at $4.86 million. Both construction and annual costs are tabulated in Table B-4, Appendix B.

Alternative 6

If it is necessary in the future to remove all sewage discharges from the bay, it may be reasonably asked whether it is cheaper to pump the effluent of the existing plants as proposed in Alternative 5 or to pump all raw sewage from the bay drainage to a new plant located near the ocean. Alternative 6 considers the latter situation. The layout for Alternative 6 (Fig. 5-4) assumes that the Richmond-Sunset plant would be expanded to accommodate the entire dry weather flow from the city of San Francisco, which will reach 135 mgd by the year 2000. Treatment units at the Southeast and North Point plants would be abandoned and the land sold at market value. The raw sewage pumping facilities at each plant would be retained, however, and would be modified to accommodate a total pumping head of 70 feet. In the case of the North Point plant, it might prove more desirable to modify both the Drumm Street pumping station and the treatment plant pumping facilities.

Under the design criteria established in Chapter 4, three stages of raw sewage pumping would be required to lift the flow over the peninsula watershed divide. Since three-stage pumping would represent a major increase in the cost of the pumping stations and a significant sacrifice in the reliability of the pumping installation, it was decided that this alternative would be evaluated on the basis of single-stage pumping combined with a tunnel through the ridge of the peninsula. The tunnel would terminate at the site of the Richmond-Sunset plant, which would be expanded by the addition of 107 mgd of primary treatment capacity. The plant addition would be constructed without influent pumping and would receive the raw sewage flow by gravity from the influent tunnel. The ocean outfall would be identical to that described for Alternative 5.

A cost breakdown of Alternative 6 is presented in Table B-5 in Appendix B. As there indicated, the total construction cost is estimated at $67.1 million. Deducting from this figure the amount which would be received from sale of surplus property at the plant site would give a net project cost of $59.2 million. The total annual cost, including allowances for the return of surplus plant property to private ownership, is estimated at $5.62 million.

Alternative 7

The final sewage disposal alternative which was investigated involves the construction of secondary treatment facilities at each of the existing primary treat-

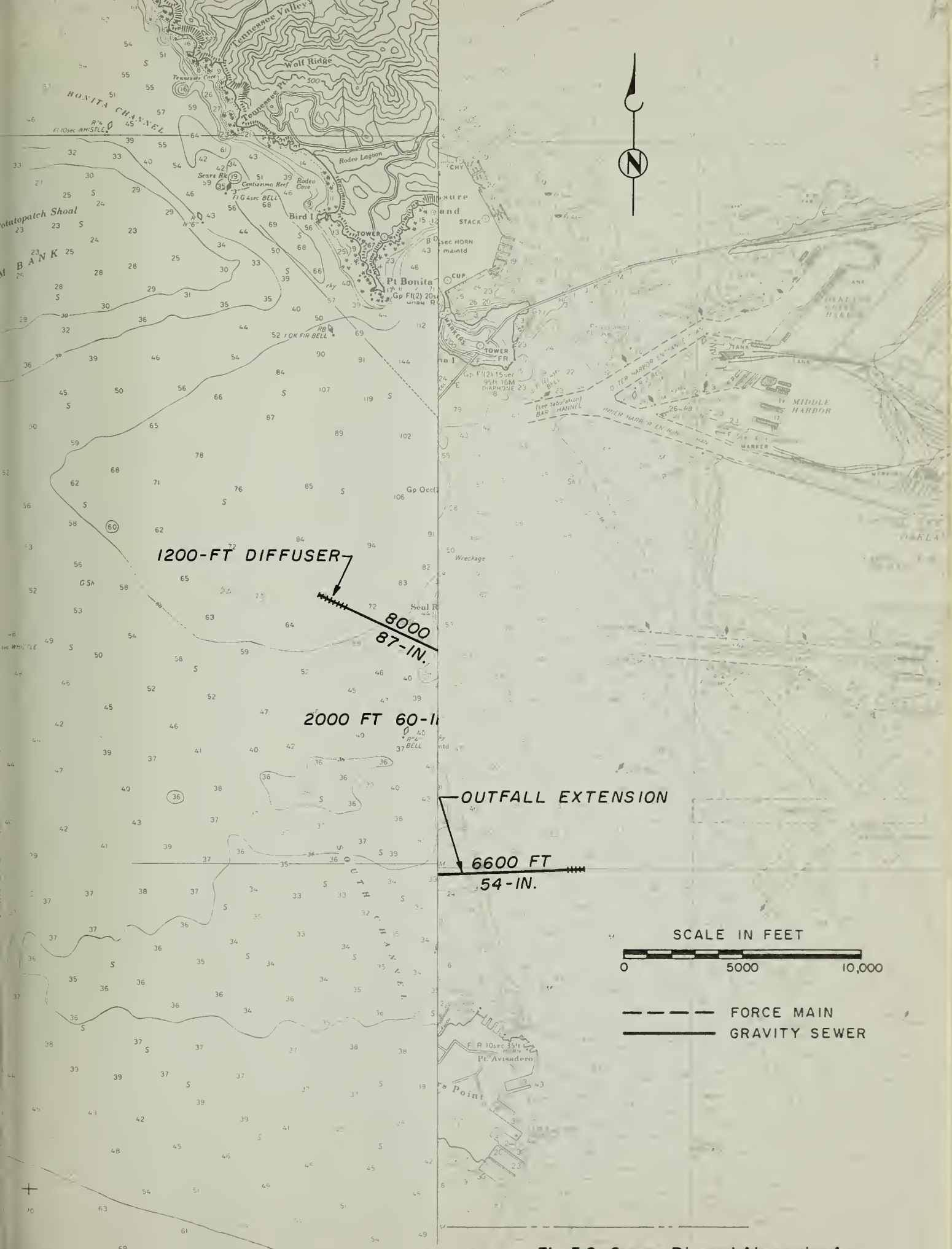

Fig. 5-2 Sewage Disposal Alternative 4

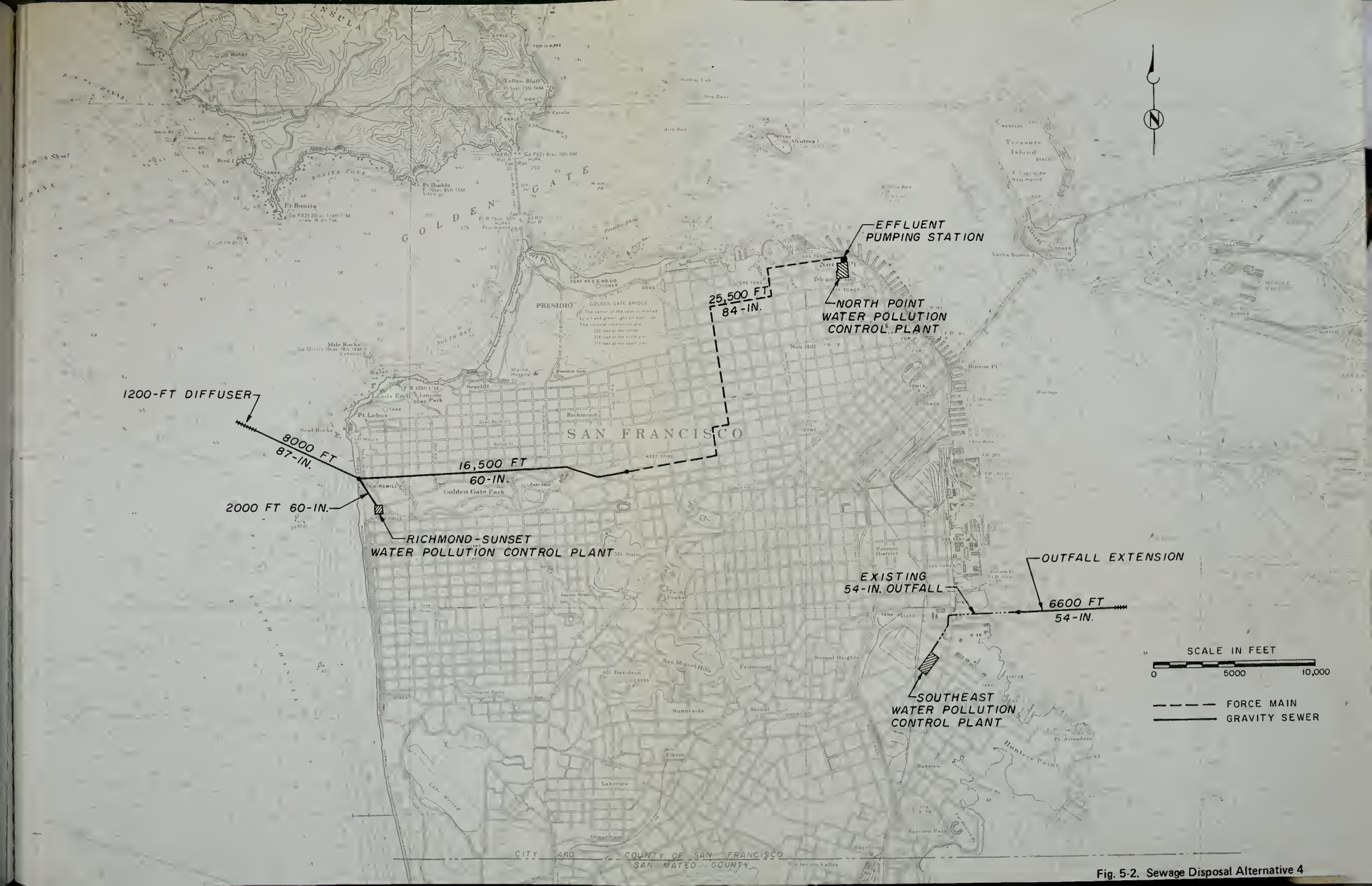

Fig. 5-2. Sewage Disposal Alternative 4

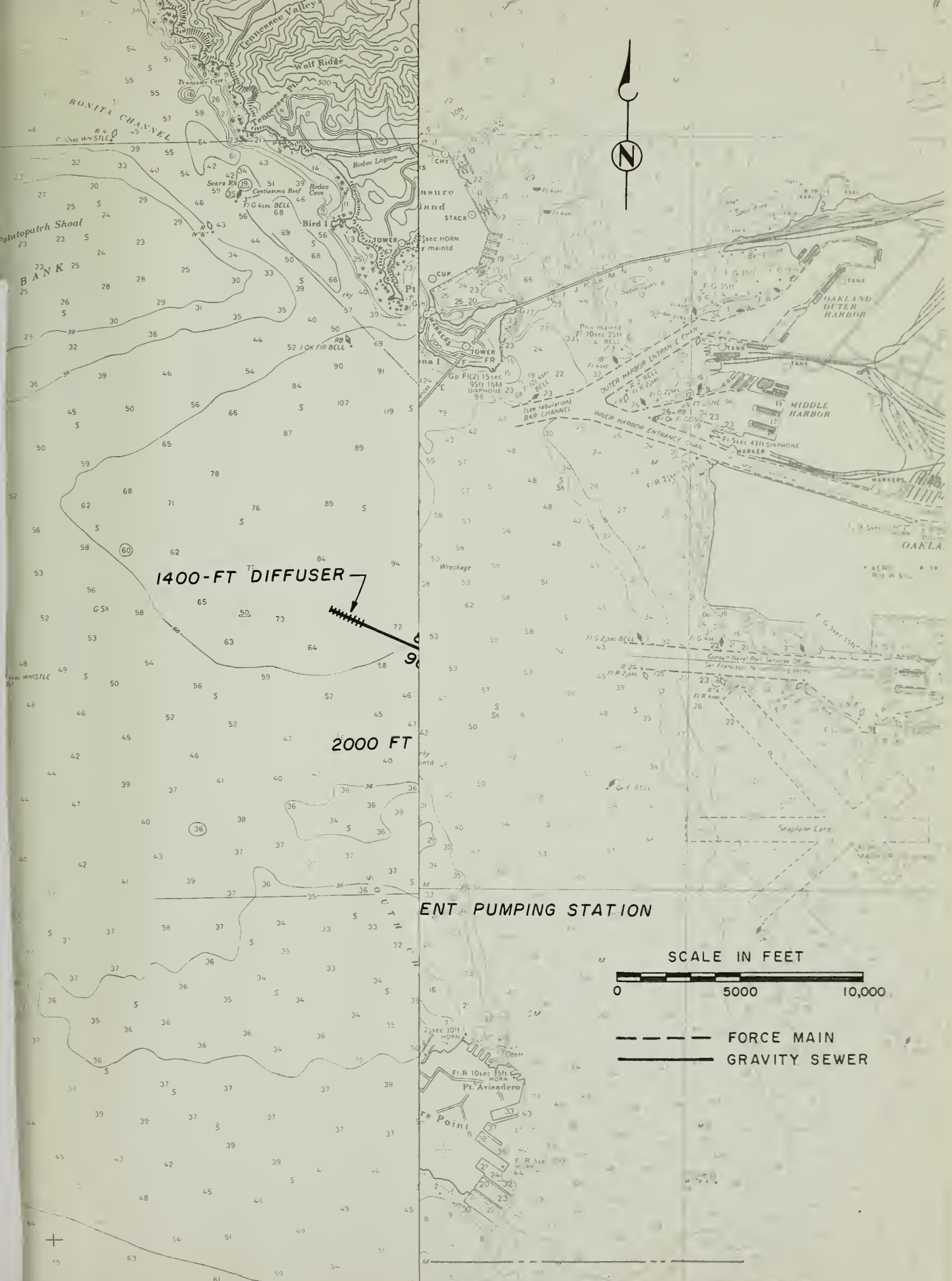

Fig. 5-3. Sewage Disposal Alternative 5

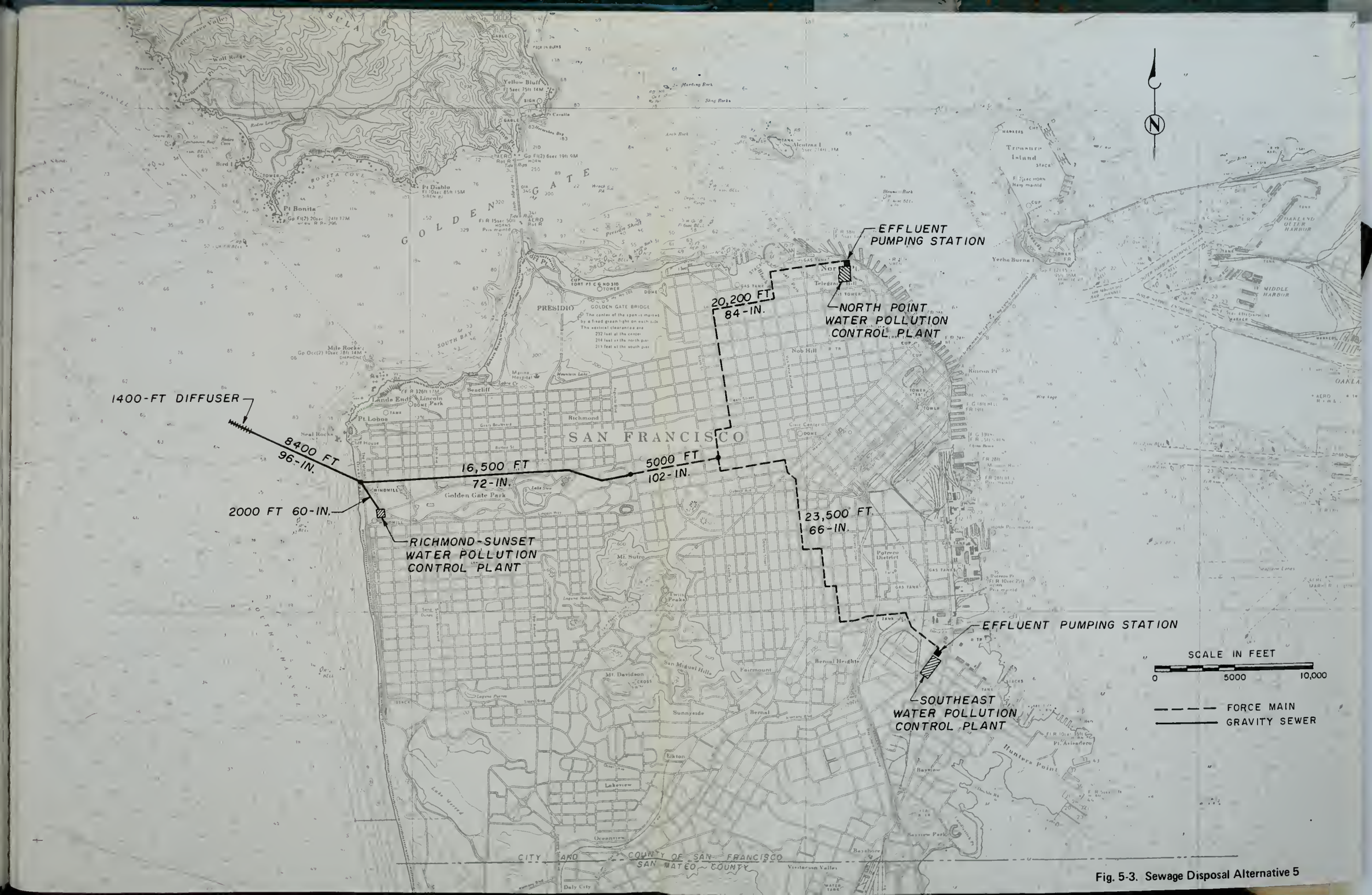

Fig. 5-3. Sewage Disposal Alternative 5

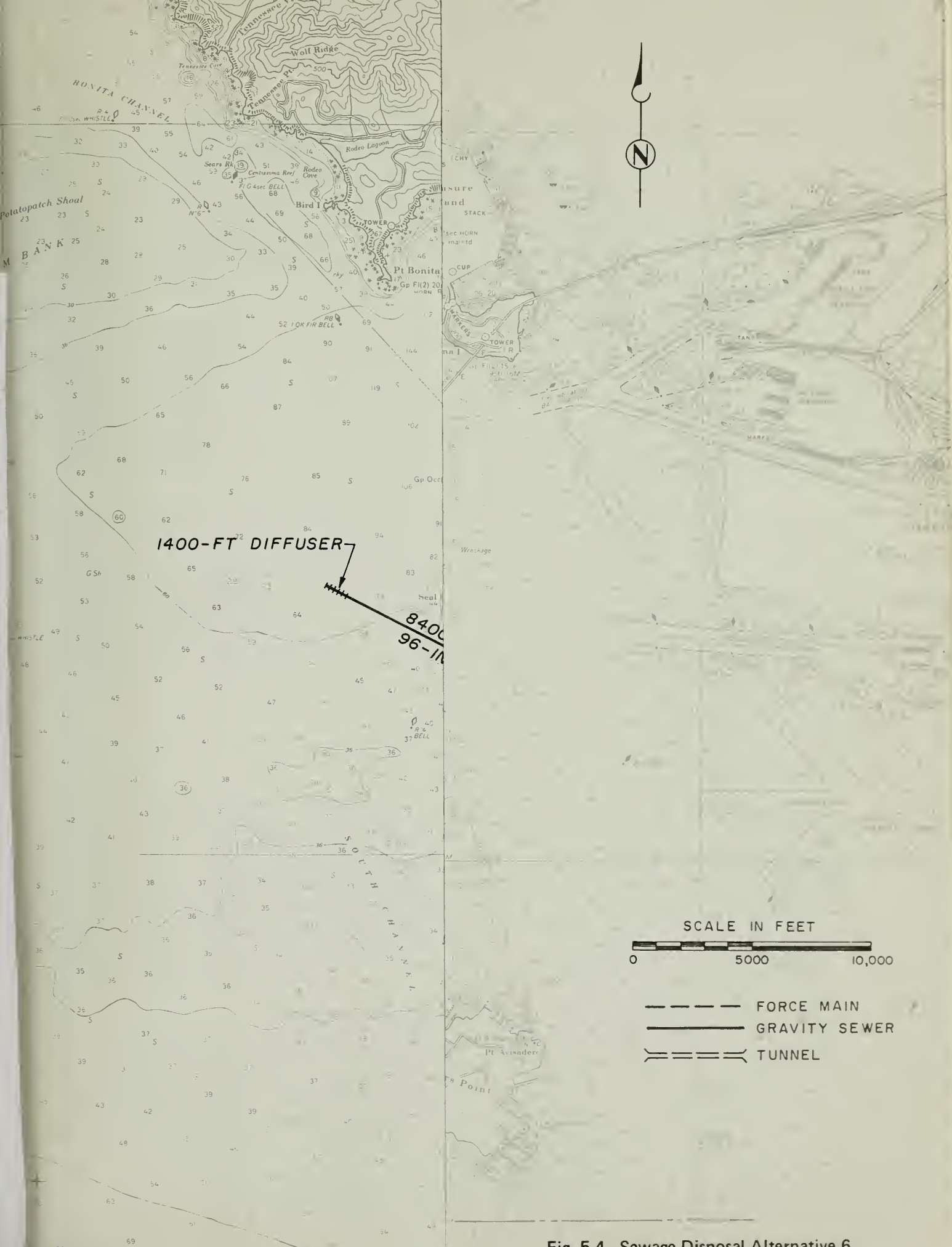

Fig. 5-4. Sewage Disposal Alternative 6

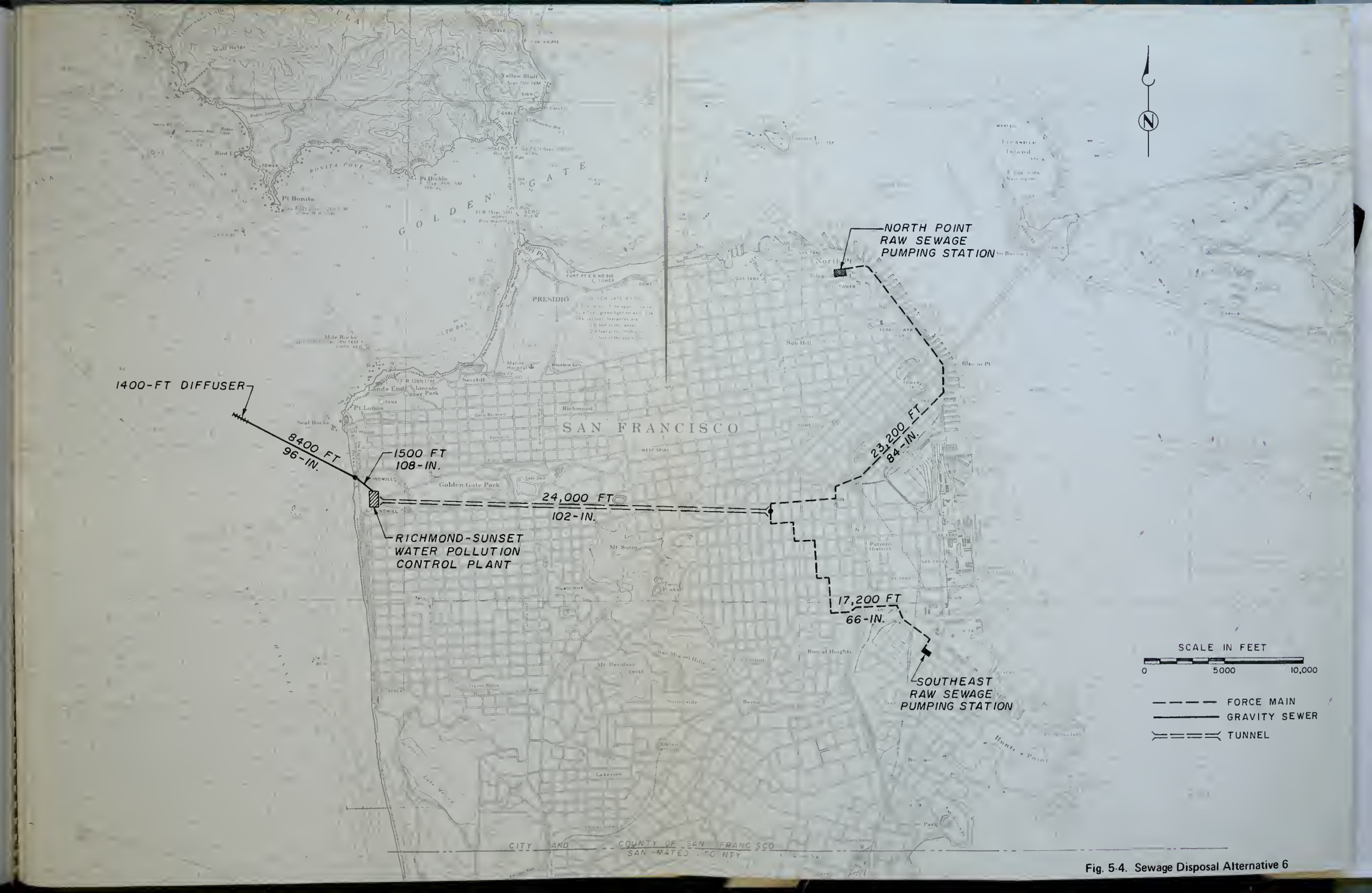

Fig. 5-4. Sewage Disposal Alternative 6

ment plants. For those plants which discharge to the bay, the reduction of pollutional load by increasing the degree of treatment offers an obvious alternative to reduction of pollutional load by exportation from the bay watershed. The secondary treatment process considered was conventional activated sludge, which is capable of removing 85 percent or more of the BOD and suspended solids in the raw sewage. It was assumed that the effluent from the activated sludge process would be of sufficiently good quality that all receiving water requirements could be met while discharging the chlorinated effluent through the existing plant outfall lines. The construction of submarine outfall lines would therefore not be required.

Preliminary plant layouts were made at each of the existing plants to determine the additional amount of land which would be required at each plant site. The layouts showed that the city-owned site at the Southeast plant is adequate for the construction of secondary treatment, but that an additional 540,000 sq ft would be required at the North Point plant. Since plant expansion at Richmond-Sunset would be constructed in Golden Gate Park, which is city-owned, the cost of additional site acquisition was not considered for this plant.

Costs for the construction of secondary treatment were taken from the plant construction cost curves presented in Chapter 4. However, since an adequate primary plant already exists in each case, the cost of secondary treatment alone was taken as the difference between the initial construction cost of a primary and a secondary treatment plant of the desired capacity. Estimated costs for Alternative 7 are presented in Appendix B, Table B-6. The total construction cost is estimated at $41.9 million, and the total cost of the project, including acquisition of additional land, at $55.9 million. Total annual cost, including allowance for land purchase and for lost tax revenue, amounts to $6.4 million.

COMPARISON OF ALTERNATIVES

In general, comparison of two or more projects to perform a given function is best accomplished by a comparison of their construction costs and total annual costs. In many cases, factors which cannot be evaluated in terms of dollars, such as esthetics and reliability must also be taken into consideration in selecting the most suitable project. The alternative projects considered in this report, however, do not all perform the same function. Each alternative differs either in the amount of pollutants discharged or in the points of discharge, and the comparative analysis must therefore consider as well the amount of necessary pollution abatement received per dollar spent.

The major characteristics of each alternative plan are listed in Table 5-2 for easy comparison. A glance at the table will show that the plans are listed in order of increasing total annual cost and in approximate order of increasing construction cost. Keeping in mind the fact that each of the alternatives considered is capable of meeting present discharge requirements and stated water quality objectives, Alternatives 6 and 7 can be dismissed immediately as impractical.

Table 5-2. Comparison of Alternative Plans

Feature	Present	Alternative plan[a]						
		1	2	3	4	5	6	7
Construction cost, million dollars[b]		8.3	8.3	18.2	24.1	31.1	59.2	55.9
Annual costs, million dollars								
Fixed costs		0.42	0.42	0.94	1.25	1.63	3.06	3.18
Operating and maintenance costs[c]	2.0[d]	2.64	2.91	2.88	3.08	3.31	2.56	3.23
Total annual cost		3.06	3.33	3.82	4.33	4.94	5.62	6.41
Dry weather flow discharged to bay, percent of total	81	79	79	47	27	0	0	79
BOD, thousand pounds per day								
Discharged to bay	92	163	132	103	60	0	0	35
Discharged to ocean	21	32	26	92	135	195	195	7

[a] See Table 5-1 for identification.

[b] Includes sale or purchase of land for plant construction.

[c] Includes cost of operating existing plants as well as new facilities.

[d] Estimated for 1968-69.

Alternative 7, which provides for secondary treatment at the three plants, has the highest total annual cost and the second highest construction cost. As shown in Chapter 3, oxygen depletion will not be a problem at the existing bay discharge points even if primary treatment is continued. The additional degree of BOD removal achieved through secondary treatment is therefore not essential to conformance with receiving water quality objectives. The Bay-Delta Program, on the other hand, postulates that the toxic and biostimulatory effects of waste discharges may in future years prove to be the criteria which govern disposal to the bay. Since conventional secondary treatment does not measurably diminish these effects, secondary treatment followed by discharge to the bay would be of no more value than primary treatment. For these reasons it was concluded that secondary treatment provides no advantage over primary treatment, and Alternative 7 was therefore rejected.

Alternative 6 involves the transfer of raw sewage out of the bay drainage for treatment with ocean disposal of effluent. Although the operating and maintenance cost of this alternative is the lowest of any plan considered because all treatment functions are consolidated in a single plant, the construction cost is the highest and the total annual cost the second highest. The result of this plan would be the discharge of all of the city's wastes to the ocean after primary treatment. The same result would be achieved by Alternative 5 at a considerably lower cost, and Alternative 6 was therefore rejected.

In consideration of the analyses presented above, it is the basic recommendation of this report that the city of San Francisco's long-range plans for disposal of dry weather sewage flow be based on the continued use of the existing treatment plants and the deep water discharge of primary effluent.

Alternatives 1, 3, 4, and 5 all involve the continued use of the existing primary treatment plants and the deep water disposal of primary effluent. The plans differ only in regard to the point of disposal. These four alternatives, therefore, lend themselves quite readily to a program of stage construction under which successive steps would be taken to export effluent from the bay drainage as necessary to meet receiving water quality criteria. Alternative 2, which considers chemical treatment as an aid to primary treatment, can be applied to any of the plans discussed.

RECOMMENDED WASTE DISPOSAL PROGRAM

As the final step in the development of a long-range program for the disposal of dry weather sewage flow from the city of San Francisco, a schedule was developed for the logical and orderly development of the recommended improvements on an incremental basis. The stage construction program is presented in Fig. 5-5 and the construction cost for each stage is set forth in Table 5-3.

Stage Construction Program

The stage construction program is designed to meet present needs and to provide the city with valid alternative courses of action in the event that future water quality control policies are more restrictive than present stated objectives. Stage 1 consists of the construction of submarine outfalls at the North Point and Richmond-Sunset plants as previously described under Alternative 1. The Southeast plant will continue to discharge through its existing outfall. The total construction cost for Stage 1 is estimated at $5.08 million.

Stage 2 consists of the extension of the Southeast outfall to the middle of the deep water channel, also as described under Alternative 1. At the end of Stage 2, all dry weather sewage flow will be discharged through submarine outfalls with diffusers located at the optimum points adjacent to the plant sites. No further capital investment is warranted to improve conditions for discharge to the bay. Rather, the next step in the staged program consists of exportation from the bay watershed of a portion of the dry weather flow. The total construction cost of Stage 2 is estimated at $3.22 million.

Stage 3 consists of the construction of an effluent pumping station at the Southeast plant and eight miles of force main and gravity sewer to convey the primary effluent to the western end of Golden Gate Park for ocean disposal. Stage 3 is substantially the same as Alternative 3, previously described. Since Stage 1 includes the construction of an ocean outfall adjacent to the Richmond-Sunset plant with a capacity of 70 mgd, the Stage 3 ocean outfall, also designed for a capacity of 70 mgd, will be substantially the same as that for Stage 1. It will, however, be constructed slightly farther north and slightly longer to allow for some physical separation of the effluent fields. The Stage 2 outfall at the Southeast plant will be retained and used for emergency bypass of plant effluent. This standby provision will justify the construction of a single-barreled effluent force main and the provision of minimum standby equipment in the effluent pumping station. Stage 3 is estimated to cost $13.5 million.

Table 5-3. Construction Cost of Recommended Program

Item	Construction cost, dollars
Stage 1	
78-inch submarine outfall 4000 feet long at North Point plant	1,800,000
54-inch submarine outfall 5000 feet long at Richmond-Sunset plant	1,680,000
Subtotal	3,480,000
Engineering and contingencies, 45 percent	1,600,000
Total construction cost, Stage 1	5,080,000
Stage 2	
Extend existing 54-inch outfall 6600 feet at Southeast plant	2,220,000
Engineering and contingencies, 45 percent	1,000,000
Total construction cost, Stage 2	3,220,000
Stage 3	
Effluent pumping station at Southeast plant, 70 mgd, 2-stage, 270 feet total head	1,800,000
27,400 feet of 66-inch force main	4,500,000
16,500 feet of 48-inch gravity sewer at 1 percent average slope	1,500,000
Subtotal	7,800,000
Engineering and contingencies, 40 percent	3,100,000
Subtotal, pipelines and pumping station	10,900,000
Ocean outfall for Southeast plant effluent, 5400 feet of 54-inch pipe	1,810,000
Engineering and contingencies, 45 percent	820,000
Subtotal, submarine outfall	2,630,000
Total construction cost, Stage 3	13,500,000
Stage 4	
Effluent pumping station at North Point plant, 150 mgd, 2-stage, 275 feet total head	2,900,000
25,500 feet of 84-inch force main	5,600,000
16,500 feet of 60-inch gravity sewer at 1 percent average slope	2,060,000
Subtotal	10,560,000
Engineering and contingencies, 40 percent	4,240,000
Subtotal, pipelines and pumping station	14,800,000
Ocean outfall for North Point plant effluent, 7000 feet of 72-inch pipe	2,930,000
Engineering and contingencies, 45 percent	1,320,000
Subtotal, submarine outfall	4,250,000
Total construction cost, Stage 4	19,100,000

Stage 4 is substantially the same as Alternative 4 and will result in the complete removal from the bay of all dry weather sewage discharges. An effluent pumping station at the North Point plant will discharge into eight miles of force main and gravity sewer which will convey North Point effluent to the ocean for disposal. A third outfall will be built west of Seal Rocks which will diffuse the 150-mgd peak flow into the mouth of the Golden Gate at a depth of 70 ft. As at the Southeast plant, the Stage 1 outfall at North Point will be retained for use as an emergency bypass. The construction cost of Stage 4 is estimated to be $19.1 million.

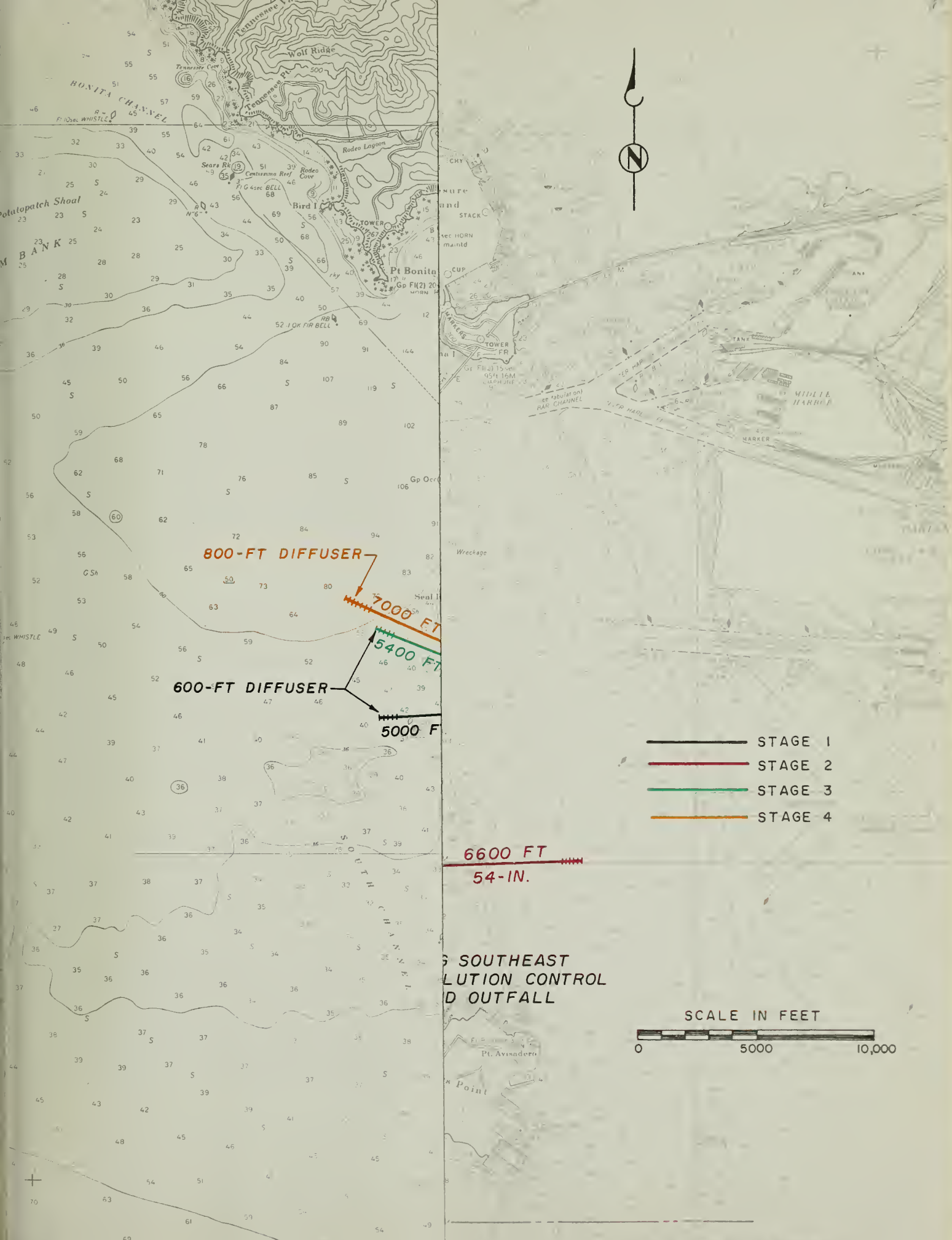

Fig. 5-5. Stage Construction Program

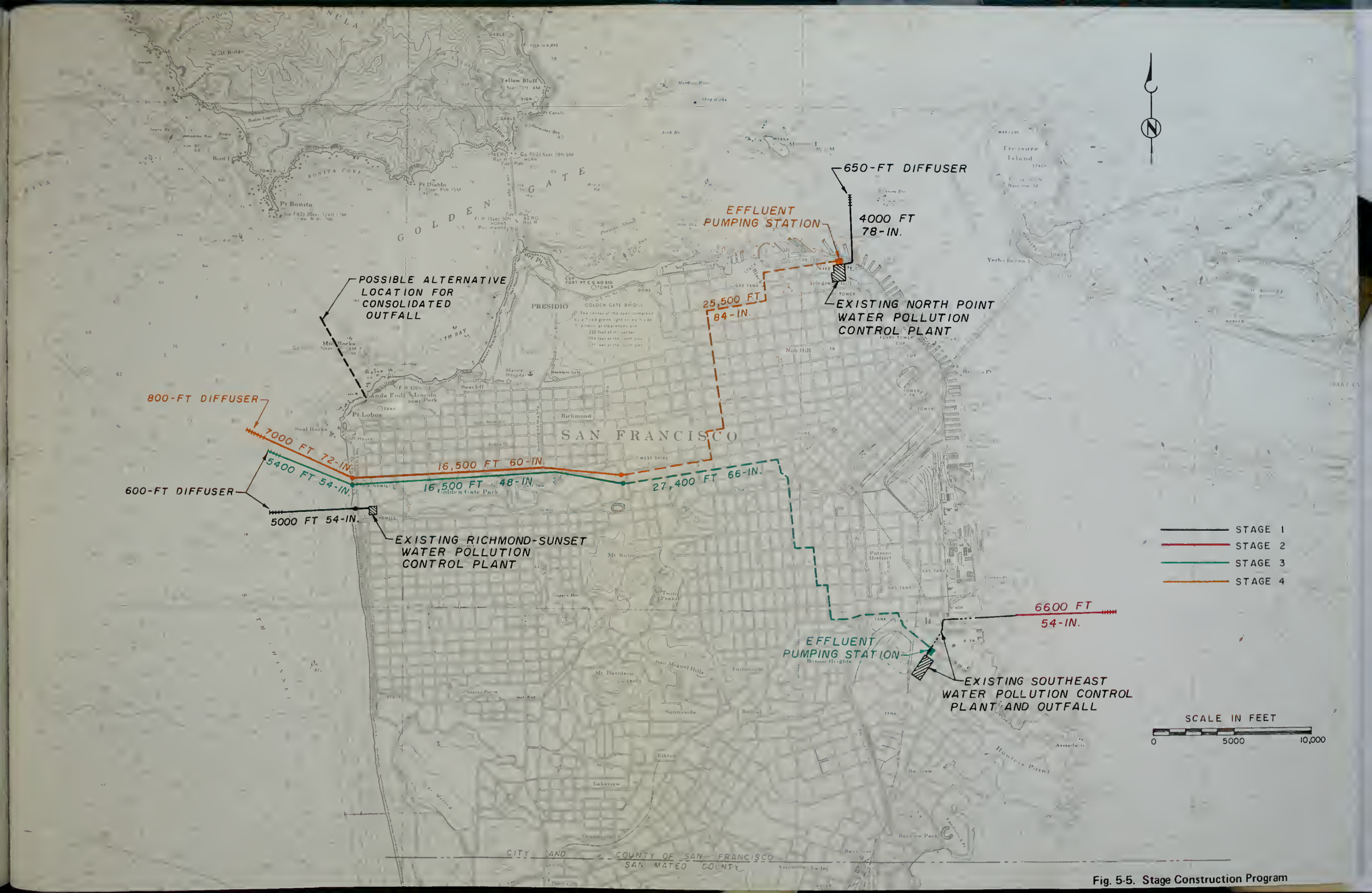

Fig. 5-5. Stage Construction Program

It must be remembered that the recommendations regarding ocean outfalls are based on assumed oceanographic factors and deal only with dry weather flows. The detailed oceanographic studies which will be required prior to outfall design may result in alterations in the length or location of the outfalls herein described. Furthermore, the studies of the treatment and disposal of wet weather flows, which are being conducted independently of this study, may indicate the advisability of using some outfalls for the dual function of dry weather and wet weather flow disposal. None of these factors will affect the basic findings of this report regarding the feasibility of submarine effluent disposal or the relative economy of the various schemes for the disposal of dry weather flows.

Construction Timing

The timing for construction of the various stages of the long-range program may be influenced by a number of factors. Among these are the quantity and quality of San Francisco wastes, the effectiveness of the treatment at the city's plants, changes in the degree of treatment or point of disposal by other major dischargers within the bay system, changing philosophy with regard to water quality control and, most of all, the implementation of the recommendations of the Bay-Delta Program. The cumulative effect of these unknown variables makes it impossible to set forth any realistic program involving actual dates, but it is possible to discuss the factors which are most likely to influence the staging.

Stage 1. Stage 1 construction is necessary to correct present conditions which are in violation of discharge requirements and should be undertaken immediately. So long as the existing treatment plants function satisfactorily, the quality of the raw waste streams does not change radically, and the quality of the bay waters is not seriously degraded by discharges from other sources, Stage 1 should adequately serve the needs of the city for dry weather sewage disposal. If violations of requirements occur, they are most likely to be related to appearance and esthetics due to the escape of floatables or to discoloration of the receiving waters as a result of plant upset or bypassing. The Southeast discharge, being the closest to shore, will be the most vulnerable to violations of this nature.

Stage 2. Stage 2, the extension of the Southeast outfall, will probably not be required for many years, if at all. It will in any case be undertaken only if experience shows that the Stage 1 installation is incapable of consistently meeting receiving water requirements.

Stages 3 and 4. Stages 3 and 4 will not be required to comply with present discharge requirements or water quality objectives. Unless fairly radical and presently unforseeable changes occur in water quality of the central bay or in waste disposal policy, it appears unlikely that Stage 3 will be required and highly improbable that Stage 4 will ever be necessary. In the event that changing conditions necessitate the construction of Stage 3, it may be practical to go directly from Stage 1 to Stage 3, bypassing Stage 2.

Effect of Chemical Treatment. The capital cost of each successive stage of the recommended program is so high that every effort should be spent to achieve maximum benefit from existing facilities before undertaking the next stage of construction. The use of coagulant aids as described under Alternative 2 may prove to be a very useful tool in improving the efficiency of the primary treatment process. Coagulant aids may also serve to reduce the incidence of violations of discharge requirements during the interim period until Stage 1 facilities can be placed in operation. It is suggested that a program of field testing and evaluation be undertaken at each of the city's primary treatment plants to assess the benefits, if any, which may be achieved through the use of chemical coagulant aids.

Effect of Bay-Delta Program. The most far-reaching effect on the waste disposal program for the city of San Francisco will be exerted by implementation of the recommendations of the Bay-Delta study. Unfortunately, the final report of the Bay-Delta Program had not been released at the time this report was written, though a preliminary copy was made available shortly before this report was printed. A brief assessment of the impact of the Bay-Delta Program on San Francisco waste disposal is included in Appendix C. Summarized briefly, it may be expected that the Bay-Delta recommendations will have no effect on the Stage 1 program recommended in this report. Subsequent stages, however, should be carefully assessed in relation to the findings of the Bay-Delta Program.

CHAPTER 6

SUMMARY AND RECOMMENDATIONS

Many of those who find it necessary to refer to this report will have neither the time nor the inclination to study it in detail. For their benefit this chapter summarizes the essential facts and presents concisely the conclusions and recommendations of the study.

EXISTING TREATMENT AND DISPOSAL FACILITIES

The city of San Francisco is divided into three sewerage service areas, each of which is served by a primary treatment plant. In this report the names of the plants also identify the drainage areas they serve. The three plants are known as the Richmond-Sunset, North Point, and Southeast Water Pollution Control Plants.

The Richmond-Sunset plant, located at the western end of Golden Gate Park, has a peak hydraulic capacity of 70 mgd and presently treats a dry weather flow of about 20 mgd. Chlorinated effluent is discharged to the Mile Rock outfall sewer, which tunnels under Fort Miley and Lincoln Park and discharges to the beach at Lands End. The plant is operating in the upper range of efficiency to be expected from a primary plant.

The North Point water pollution control plant is situated on Bay Street at the foot of Telegraph Hill. Peak hydraulic capacity is 150 mgd and present average dry weather flow is 57 mgd. Operating records show that this plant also achieves better than average treatment efficiencies. After chlorination the plant effluent is discharged to the bay about 10 ft below water at the seaward ends of Piers 33 and 35. Sludge removed from the North Point sedimentation tanks is not treated at that plant but is pumped to the Southeast plant for treatment and disposal.

The Southeast plant provides conventional primary treatment for an average dry weather flow of 18 mgd and a peak flow of 70 mgd. In addition the plant digests and processes the sludge from its own primary tanks and from the North Point plant. Effluent from the Southeast plant is discharged through a submarine outfall which extends about 800 ft offshore.

SEWAGE DISPOSAL REQUIREMENTS AND METHODS

Each time a community undertakes the obligation to provide sewage service for its residents, it assumes the attending obligation of satisfactory disposal of the

collected sewage. In the San Francisco Bay area, disposal requirements and policy are established by Regional Water Quality Control Board No. 2. Summarized briefly, disposal requirements for San Francisco Bay are established with the following goals in mind:

1. The maintenance of a bacterial quality in the waters of the bay which will be suitable for water contact sports.

2. The prevention of nuisance conditions due to odors, unsightliness, or discoloration of the receiving waters.

3. The prevention of conditions which will be toxic to native marine biota.

4. The prevention of over-enrichment of the receiving waters by the nutrients in waste discharges which could result in objectionable biologic growths.

Discharge requirements for the Pacific Ocean are established with the same basic objectives as for the bay, though the massive dilution available generally minimizes problems associated with toxicity and biostimulation.

The capacity of a marine environment to accept sewage and render it harmless depends on the oceanographic characteristics of the receiving waters and on the manner in which the waste is introduced into the receiving water. There is abundant evidence to indicate that sewage can be satisfactorily disposed of through submarine discharge to the Pacific Ocean after primary treatment. A trial analysis, based on certain assumptions as to oceanographic characteristics, showed that under the assumed conditions the total dry weather flow from the city of San Francisco in the year 2000 could be satisfactorily disposed of after primary treatment by discharge through a submarine outfall terminating about 6000 ft west of Seal Rocks at a depth of 80 ft.

Disposal to San Francisco Bay cannot be discussed solely in the context of the individual discharger, but must consider as well the cumulative effect of all wastes discharged to the bay, both present and future. From the standpoint of the city of San Francisco, it is important to know not only what the quality of adjacent bay waters will be but also what effect San Francisco discharges will have on those waters. This task was accomplished through the application of a computer program developed by Water Resources Engineers in connection with the San Francisco Bay-Delta Water Quality Control Program. Waste loadings for the year 2020, as developed for use in the Bay-Delta Program, were fed into a mathematical model of San Francisco Bay. For San Francisco, waste inputs were assumed to be primary effluent with flow rates in accordance with projections by the Department of Public Works. The computer program was run for an equivalent prototype time of 62 tidal cycles, or about 65 days. At the end of that time the program determined BOD, dissolved oxygen, and concentration of a hypothetical conservative pollutant used to represent toxicity. The value for each of the above water quality factors was calculated both with and without the San Francisco waste discharges.

The results of the computer program made it clear that while some areas of the bay system would be seriously degraded by the assumed waste inputs, the central bay west of the San Francisco Bay Bridge would not be adversely affected even with the continued discharge of wastes presently being discharged to the bay. Receiving water conditions south of the San Francisco Bay Bridge within the sphere of influence of the San Francisco waste discharges would be of slightly poorer quality than in the North Point area, but with no clear indication that future water quality objectives can not be met.

DESIGN CRITERIA AND BASIS OF COST ESTIMATES

Prior to laying out alternative projects for evaluation it is necessary to establish design criteria applicable to all major sewerage facilities and to develop cost data for all elements of the alternative projects. Since this study is concerned only with the disposal of dry weather waste flows, records collected at the city's three sewage treatment plants were used as the basis for present unit strength and flow factors. Future values projected to the year 2000 were furnished by the San Francisco Department of Public Works.

Construction costs in this report are based on preliminary layouts of the proposed sewerage improvements. For estimating purposes, prices of comparable work were obtained from available sources of current information. For the costs of pumping stations and sewage treatment plants heavy reliance was placed on the actual cost of projects designed by Brown and Caldwell. Costs for sewers and force mains, on the other hand, were developed from an analysis of approximately 40 recent construction projects involving large pipe laid in San Francisco city streets.

Annual costs include operation, maintenance, administration, depreciation, and interest on borrowed capital. For projects which involve the sale or acquisition of land, the cost of the sale or purchase was considered as an annual cost. The effect of adding or subtracting property from the tax rolls was also evaluated. Operation and maintenance costs for sewage treatment plants were adjusted to reflect the actual recorded cost of sewage treatment at the city's three existing plants.

SEWAGE DISPOSAL ALTERNATIVES

A total of seven alternative schemes for the disposal of dry weather sewage flows were developed and analyzed for construction cost and total annual cost. Each alternative is technically feasible and each is capable of meeting the present requirements and stated water quality objectives of the Water Quality Control Board. The major features of each alternative are summarized below.

Alternative 1

The first alternative considers deep water disposal of the effluent from each of the city's three plants at a point adjacent to the plant site. Each plant would

continue to provide primary treatment. The outfall at the Richmond-Sunset plant would extend 5000 ft due west of the plant, terminating at a depth of 40 ft. The North Point outfall would begin in the vicinity of Piers 33 and 35 and would extend 4000 ft northward to the center of the deep water channel, terminating at a depth of 80 ft. The Southeast plant has an existing submarine outfall which had been constructed but had not yet been placed in operation when this report was written. The present outfall is considered adequate for compliance with existing requirements, but for planning purposes Alternative 1 includes the cost of extending the outfall 6600 ft to the center of the deep water channel.

Construction costs for Alternative 1 are estimated at $8.3 million. The total annual cost is estimated to be $3.1 million.

Alternative 2

Alternative 2 considers the use of polyelectrolytes as coagulant aids to improve the efficiency of conventional primary treatment. This alternative is considered only in conjunction with Alternative 1, but could in fact be applied to any of the other alternatives considered. Alternative 2 would require no additional capital cost, and under the assumed conditions of use would achieve a 25 percent increase in the efficiency of primary treatment at an annual cost of $270,000.

Alternative 3

The third alternative considers exporting the effluent from the Southeast treatment plant to an ocean outfall which would discharge about a mile west of Seal Rocks. The North Point plant would continue to discharge to the bay as described in Alternative 1. Estimated costs are $18.3 million for construction cost and $3.8 million for total annual cost.

Alternative 4

Alternative 4 considers the exportation of effluent from the North Point plant while continuing to discharge primary effluent from the Southeast plant. The ocean outfall would be in the same location as for Alternative 3, but would extend seaward about 1000 ft farther. Costs for Alternative 4 are $24.1 million and $4.3 million for construction and total annual costs, respectively.

Alternative 5

It is worthwhile to consider an alternative which would exclude all dry weather sewage discharges from the bay. Alternative 5 would export the effluent from both the North Point and the Southeast plants, substantially as described in Alternatives 3 and 4. Construction cost for Alternative 5 is estimated at $31.1 million, and total annual cost at $4.9 million.

Alternative 6

A second method of excluding all San Francisco sewage discharges from the bay would be to pump raw sewage from the North Point and Southeast services areas

to an expanded Richmond-Sunset plant. Primary effluent would be discharged to the ocean as in Alternative 5. The construction cost for this alternative would be $59.2 million, and the total annual cost $5.6 million.

Alternative 7

The final alternative which was investigated would involve the construction of secondary treatment facilities at each of the existing primary plants and the continued discharge of chlorinated effluent through the existing outfall lines. Construction cost would be $55.9 million and total annual cost $6.4 million.

Recommended Waste Disposal Program

The alternative projects were compared on the basis of construction and annual cost as well as the amount of necessary pollution abatement received per dollar spent, and a long-range program was developed to provide for logical and orderly development of recommended improvements on an incremental basis. It is the basic recommendation of this program that the city's long-range plans for disposal of dry weather sewage flow be based on continued use of the existing treatment plants and the deep water discharge of primary effluent.

Stage 1 of the recommended program consists of the construction of deep water outfalls at the North Point and Richmond-Sunset plants. Estimated construction cost is $5.08 million. Stage 2 involves the extension of the Southeast outfall, estimated to cost $3.22 million. Stage 3 consists of the exportation of effluent from the Southeast plant to an ocean outfall, and Stage 4 consists of the exportation of North Point plant effluent to an ocean outfall. The construction costs of Stages 3 and 4 are $13.5 million and $19.1 million respectively.

Stage 1 is required now to correct present conditions which are in violation of discharge requirements. Subsequent stages of construction will be undertaken only as the need becomes apparent. Unless unforseeable changes occur in water quality of the central bay or in waste disposal policy, it appears unlikely that Stage 3 will be required and highly improbable that Stage 4 will ever be necessary.

RECOMMENDATIONS

As a result of our study of the disposal of dry weather sewage flows from the City and County of San Francisco we recommend:

1. That the City and County of San Francisco adopt, as its long-range program for disposal of dry weather sewage flow, the recommended program presented in this report.

2. That the stage construction program presented in Chapter 5 be adopted as a guide to the orderly development of the long-range program, and that the neces-

sary steps be taken to arrange for the financing, design and construction of those projects which are scheduled for Stage 1.

3. That a program of field testing and evaluation be undertaken at each of the city's three sewage treatment plants to assess the benefits, if any, which may be achieved through the use of chemical coagulant aids.

4. That a study program be undertaken to evaluate the oceanographic characteristics of the recommended deep water disposal sites in order to verify the suitability of the sites and collect the information required for submarine outfall design.

APPENDIX A

REFERENCES

1. United States Department of Health, Education and Welfare, Public Health Service. National Shellfish Sanitation Program Manual of Operations, Part I, Sanitation of Shellfish Growing Areas. 1965 revision.

2. Rawn, Bowerman, and Brooks. Diffusers for Disposing of Sewage in Sea Water. Journal of the Sanitary Engineering Division, American Society of Civil Engineers. March, 1960.

3. Whitt, M. L. Oceanographic Influences on Outfall Design. Bulletin, California Water Pollution Control Association. January, 1966.

4. Brooks, N. H. Methods of Analysis of the Performance of Ocean Outfall Diffusers. A report to Hyperion Engineers. April, 1956.

5. Brown and Caldwell. Marin County Sewerage Study. October, 1967.

6. Pearson, E. A. An Investigation of the Efficacy of Submarine Outfall Disposal of Sewage and Digested Sludge. California State Water Pollution Control Board Publication No. 14, 1956.

7. Hyperion Engineers. Ocean Outfall Design. October, 1957.

8. State of California Water Quality Control Board. San Francisco Bay-Delta Water Quality Control Program, Task VII-1a, Special Oceanographic Studies. June, 1968.

9. United States Army Engineer District, San Francisco, Corps of Engineers. Comprehensive Survey of San Francisco Bay and Tributaries, California. March, 1963.

APPENDIX B

Table B-1. Alternative 1, Construction and Annual Costs

Item	Cost, dollars
Construction Cost	
North Point plant: Construct 78-inch outfall 4,000 feet long	1,800,000
Southeast plant: Extend existing 54-inch outfall 6,600 feet as planned by City for Stages 2 and 3	2,220,000
Richmond-Sunset plant: Construct 54-inch outfall 5,000 feet long	1,680,000
Subtotal	5,700,000
Engineering and contingencies, 45 percent	2,600,000
Total construction cost	8,300,000
Annual Cost	
Fixed costs	420,000
Operation and maintenance costs	
Pipelines	25,000
North Point plant	1,070,000
Southeast plant	680,000
Richmond-Sunset plant	580,000
Effluent chlorinatin at 15 mg/l	
North Point and Southeast plants, chlorine purchased in carload lots	195,000
Richmond-Sunset plant, chlorine purchased in in ton cylinders	92,000
Total annual cost	3,060,000

Table B-2. Alternative 3, Construction and Annual Costs

Item	Cost, dollars
Construction Cost	
Effluent pumping station at Southeast plant, 70 mgd, 2-stage, 270 foot total head	1,800,000
27,400 feet of 66-inch force main	4,500,000
16,500 feet of 48-inch gravity sewer at 1 percent average slope	1,500,000
2000 feet of 60-inch gravity sewer at 0.2 percent average slope	250,000
Subtotal	8,050,000
Engineering and contingencies, 40 percent	3,250,000
Subtotal, pipelines and pumping stations	11,300,000
North Point submarine outfall, same as Alternative 1, Table B-1	1,800,000
Ocean outfall, 7,000 feet of 72-inch pipe	2,930,000
Subtotal	4,730,000
Engineering and contingencies, 45 percent	2,170,000
Subtotal, submarine outfalls	6,900,000
Total construction cost, Alternative 3	18,200,000
Annual Cost	
Fixed costs	940,000
Operation and maintenance costs	
Pipelines	47,000
Effluent pumping station	76,000
North Point plant	1,070,000
Southeast plant	680,000
Richmond-Sunset plant	580,000
Effluent chlorination, same as Alternative 1, Table B-1	287,000
Power for effluent pumping	140,000
Total annual cost, Alternative 3	3,820,000

Table B-3. Alternative 4, Construction and Annual Costs

Item	Cost, dollars
Construction Cost	
Effluent pumping station at North Point plant, 150 mgd, 2-stage, 275 feet total head	2,900,000
25,500 feet of 84-inch force main	5,600,000
16,500 feet of 60-inch gravity sewer at 1 percent average slope	2,060,000
2,000 feet of 60-inch gravity sewer at 0.2 percent average slope	250,000
Subtotal	10,810,000
Engineering and contingencies, 40 percent	4,290,000
Subtotal, pipelines and pumping stations	15,100,000
Southeast submarine outfall extension, same as Alternative 1, Table B-1	2,220,000
Ocean outfall, 8,000 feet of 87-inch pipe	4,000,000
Subtotal	6,220,000
Engineering and contingencies, 45 percent	2,780,000
Subtotal, submarine outfalls	9,000,000
Total construction cost, Alternative 4	24,100,000
Annual Cost	
Fixed costs	1,250,000
Operation and maintenance costs	
Pipelines	60,000
Effluent pumping station	120,000
North Point plant	1,070,000
Southeast plant	680,000
Richmond-Sunset plant	580,000
Effluent chlorination, same as Alternative 1, Table B-1	287,000
Power for effluent pumping	280,000
Total annual cost, Alternative 4	4,330,000

Table B-4. Alternative 5, Construction and Annual Costs

Item	Cost, dollars
Construction Cost	
Effluent pumping station at North Point plant, 150 mgd, 2-stage, 275 feet total head	2,900,000
Effluent pumping station at Southeast plant, 70 mgd, 2-stage 270 feet total head	1,800,000
20,200 feet of 84-inch force main	4,400,000
23,500 feet of 66-inch force main	3,850,000
5,000 feet of 102-inch force main	1,450,000
16,500 feet of 72-inch gravity sewer at 1 percent average slope	2,700,000
2,000 feet of 60-inch gravity sewer at 0.2 percent average slope	250,000
Subtotal	17,350,000
Engineering and contingencies, 40 percent	6,950,000
Subtotal, pipelines and pumping stations	24,300,000
Ocean outfall, 8,400 feet of 96-inch pipe	4,700,000
Engineering and contingencies, 45 percent	2,100,000
Subtotal, submarine outfall	6,800,000
Total construction cost, Alternative 5	31,100,000
Annual Cost	
Fixed costs	1,630,000
Operation and maintenance costs	
Pipelines	74,000
Effluent pumping stations	196,000
North Point plant	1,070,000
Southeast plant	680,000
Richmond-Sunset plant	580,000
Effluent chlorination, same as Alternative 1, Table B-1	287,000
Power for effluent pumping	420,000
Total annual cost, Alternative 5	4,940,000

Table B-5. Alternative 6, Construction and Annual Costs

Item	Cost, dollars
Construction Cost	
Modify North Point influent pumping to provide a raw sewage pumping lift of 70 feet	900,000
Modify Southeast influent pumping to provide a raw sewage pumping lift of 70 feet	500,000
23,200 feet of 84-inch force main	5,100,000
17,200 feet of 66-inch force main	2,800,000
24,000 feet of 102-inch tunnel, 0.1 percent slope	15,600,000
Construct an additional 107 mgd of primary treatment without influent pumping at the Richmond-Sunset plant	17,800,000
1,500 feet of 108-inch land outfall, 0.2 percent slope	380,000
Subtotal	43,080,000
Engineering and contingencies, 40 percent	17,220,000
Subtotal, plants and pipelines	60,300,000
Ocean outfall, 8,400 feet of 96-inch pipe	4,700,000
Engineering and contingencies, 45 percent	2,100,000
Subtotal, submarine outfall	6,800,000
Total construction cost, Alternative 6	67,100,000
Sale of site of North Point primary treatment, 170,000 square feet at $25	(4,300,000)
Sale of site of Southeast primary treatment, 900,000 square feet at $4	(3,600,000)
Total project cost, Alternative 6	59,200,000
Annual Cost	
Fixed costs	
Treatment plant and pumping stations	1,590,000
Pipelines	2,030,000
Income from sale of surplus property at existing plant sites (deduct)	(360,000)
Tax income from property returned to tax rolls (deduct)	(200,000)
Operation and maintenance costs	
Pipelines	120,000
Raw sewage pumping stations	280,000
Richmond-Sunset treatment plant, 135 mgd primary	1,600,000
Effluent chlorination at 15 mg/l, chlorine purchased in ton containers	440,000
Power for raw sewage transfer pumping	120,000
Total annual cost, Alternative 6	5,620,000

Table B-6. Alternative 7, Construction and Annual Costs

Item	Cost, dollars
Construction Cost	
Construct secondary treatment at North Point plant, 71 mgd, 85 percent BOD removal	15,000,000
Construct secondary treatment at Southeast plant, 36 mgd, 85 percent BOD removal	8,300,000
Construct secondary treatment at Richmond-Sunset plant, 28 mgd, 85 percent BOD removal	6,600,000
Subtotal	29,900,000
Engineering and contingencies, 40 percent	12,000,000
Total construction cost, Alternative 7	41,900,000
Cost of 540,000 sq ft of additional land at North Point plant site	14,000,000
Total project cost, Alternative 7	55,900,000
Annual Cost	
Fixed costs	
Secondary treatment works	2,470,000
Purchase of additional site	710,000
Operation and maintenance costs	
North Point plant	1,260,000
Southeast plant	810,000
Richmond-Sunset plant	700,000
Effluent chlorination at 5 mg/l	
North Point and Southeast plants, chlorine purchased in carload lots	65,000
Richmond-Sunset plant, chlorine purchased in ton containers	31,000
Annual tax revenue lost through purchase of land for secondary treatment	360,000
Total annual cost, Alternative 7	6,410,000

APPENDIX C

EFFECT OF BAY-DELTA WATER QUALITY CONTROL PROGRAM ON RECOMMENDATIONS OF THIS REPORT

The scope of this report was limited to consideration of sewage effluent disposal from the city of San Francisco only. The Bay-Delta Program, on the other hand, considers the sewerage problems of the entire region from Sacramento and Calistoga to San Jose. If the major recommendations of the Bay-Delta Program are adopted, a 12-county regional agency will be formed and empowered to design, build and operate a regional wastewater system. It is particularly important, therefore, that any initial steps in water quality enhancement by the city of San Francisco be consistent with the goals of the Bay-Delta Program.

A preliminary edition of the San Francisco Bay-Delta Water Quality Control Program final report was reviewed to assess the extent to which the goals of that report are compatible with the conclusions reached during this study of effluent disposal alternatives for the city of San Francisco. Several important factors were noted in the review.

1. Stage 1 as recommended in this report is identical to recommendations for San Francisco in Phase One of the Bay-Delta Program, scheduled for completion in 1980. For the next ten years, therefore, there is no difference in the recommendations of the two reports.

2. The Bay-Delta Program recommends ocean discharge adjacent to the plant site as the long-range solution for effluent disposal at the Richmond-Sunset plant. In this respect the recommendations of the Bay-Delta Program and this report are identical.

3. Phase Two of the Bay-Delta Program foresees the construction of a bayshore interceptor to convey raw sewage from the North Point and Southeast drainage areas to Redwood City for primary treatment and ocean disposal. Either this plan or the plan described in Stages 3 and 4 of this report may be considered a technically feasible method of removing San Francisco's dry weather sewage flow from San Francisco Bay. Further study will be required to determine which plan is most economical and whether either plan is necessary.

4. The Bay-Delta Program recommends in Phase Two the construction of a regional ocean outfall system extending into deep water (200 ft or more) off the southern San Mateo coast. At that depth the effluent field is expected to remain submerged throughout most of the year. This report recommends discharge of effluent through outfall systems extending to depths of 40 to 90 ft. The greater

depth is advisable for the massive flows anticipated from a regional system. For the smaller flows emanating from the city of San Francisco, which will be discharged to an area of intense horizontal and vertical mixing, the shallower depths of discharge are technically feasible.

In summary, San Francisco may proceed with Stage 1 as recommended in this report with complete confidence that its plans will not be in conflict with the Bay-Delta Water Quality Control Program. After Stage 1 construction is completed there will be ample time to study future stages and select the plan which will offer maximum economy to the city of San Francisco and will adequately protect the quality of the waters of San Francisco Bay.

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